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If I fell out of a commercial aircraft, would I be dead before I hit the ground? →p79

FROM THE EDITOR

Our attitude to meat and dairy in the UK is evolving, and you only have to visit a local supermarket to see it. Alongside the meat and dairy aisles, now sit shelves crammed full of plant-based alternatives. There are juicy burgers made out of pea proteins, chicken nuggets made from mushrooms and crispy bacon made from tofu. And if there was any doubt, the world's biggest fast-food chains all now serve some form of plant-based alternative to their trademark burgers. The public wants to eat less meat, but it doesn't want to cut out its favourite foods – especially not the ones that are quick and easy to cook.

What's driving the change? Of course, many have long chosen meat-free diets because they can't stomach modern farming practices. But more recently, it seems as though consumers are coming to terms with the effect their appetite has on the environment. As well as being good for your health, cutting down on the amount of meat you eat is one of the most powerful personal changes you can make to reduce your carbon footprint. All of the above point to one conclusion: there's money to be made if someone can faithfully recreate meat, without the need for livestock farming. Biotech companies around the globe have spotted this opportunity and now the race is on. Indeed, in some parts of the world you can already buy a plate of meat that's been grown in a bioreactor, rather than on a farm. It's just a matter of time before slaughter-free alternatives make it to our shop shelves. To discover what we know so far about 'cultivated meat', head to p54.

Daniel Bennett, Editor

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ON THE BBC THIS MONTH...

Our Changing Planet
In this hugely ambitious series, six presenters visit six of the world's most threatened ecosystems and will return over a period of seven years to witness conservation projects in action, to see whether we can protect our planet's treasures.
BBC One
Sundays, 7pm
Catch up on iPlayer

CrowdScience
Photographic memory: it's a gimmick employed by many a TV and movie series, but does it really exist? This week, *CrowdScience* explores the elusive world of memory.
BBC World Service
13 May, 8:30pm
Also available on BBC Sounds

Just One Thing
Dr Michael Mosley returns for his health radio series, which examines the small steps we can all take to improve our health. In this series, he starts with beetroot.
BBC Radio 4
Wednesdays, 9:30am
Also available on BBC Sounds

CONTRIBUTORS

PROF CHRIS BAIL
We're all tired of the neverending rage fest that social media sites have become. Chris has created a social network from scratch in the lab, to see if he can build something better. →p26

VICTORIA WOOLLASTON
Victoria, a tech and lifestyle journalist and founder of **mamabella.uk**, digs into whether microbiome-friendly skincare really works. →p32

DR HELEN SCALES
Seashells are universally adored, but how much do you really know about them? Marine biologist Helen reveals what a shell's form and patterning can tell us about its previous owner. →p44

JULES HOWARD
For zoologist Jules there's one animal he loves more than any other, and that's his pet dog. But are the feelings mutual? Join him as he finds out more about dog psychology. →p72

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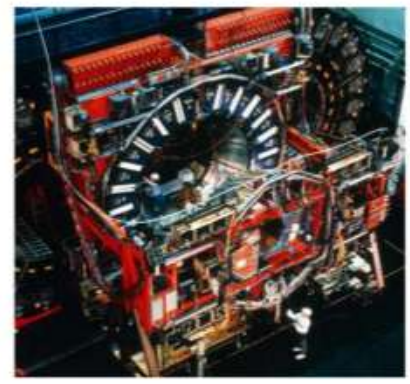

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ROBERT DEPALMA

“WITHOUT THIS IMPACT EVENT, IF THE DINOSAURS WERE NOT TAKEN OUT, IT’S POSSIBLE THAT HUMANS MIGHT NEVER HAVE COME TO BE”

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EYE OPENER

In the heights

VAN PROVINCE, TURKEY

With its deep valleys and high mountains, the Gevaş district in the Van province of Turkey is an ideal location for a wind farm. In fact, it's one of the country's most productive areas in terms of sustainable wind energy. The engineer you can see on the turbine is safely tethered to a guard rail.

High up in the mountains, cold air is denser and heavier than warm air. Gaps between mountains funnel and intensify winds, and the strong but consistent breezes mean that wind farms can produce more power. At an altitude of 3,000m, the wind turbines at Gevaş also have snow and blizzards to contend with, not to mention ice formation, but the payoff is enough electricity to supply 50,000 houses.

In Turkey, wind power usually generates around 10 per cent of the country's electricity, but in early April this year, daily wind generation hit an all-time high when more than 25 per cent of total electricity came from wind power.

GETTY IMAGES

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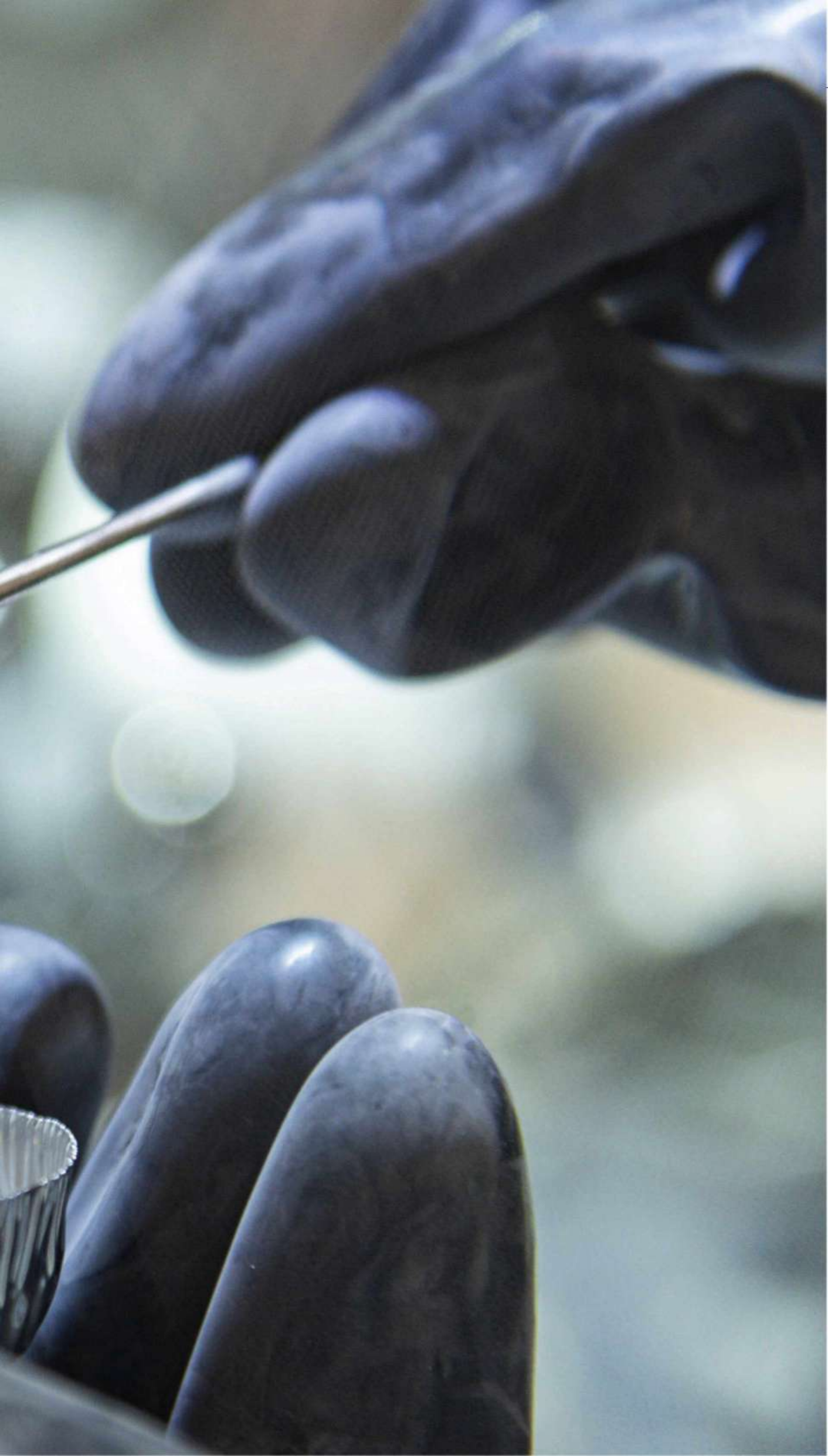

EYE OPENER

Time capsule

JOHNSON SPACE CENTER HOUSTON, TEXAS

Scientists are beginning to unravel the layers of ancient history preserved within this pristine lunar soil sample, which has been vacuum sealed for 50 years. The sample was collected by the Apollo 17 astronauts in 1972. They hammered a thin, cylindrical sample-collection device (called a drive tube) into a landslide deposit from the Taurus-Littrow Valley, in the Moon's northern hemisphere. They then sealed it up before returning to Earth.

But extracting the sample from the tube was a tricky operation. When the sample was collected, the temperature was very cold, so there was the potential for volatiles and lunar gases to be preserved. The team needed to find a way to collect this precious gas, as well as the solids.

Prior to opening, CT scans were taken, high-resolution 3D images were created, and several dry runs were carried out to ensure the operation went without a hitch.

NASA/JSC

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EYE OPENER

Life of slime

BUCKINGHAMSHIRE, UK

You'd be forgiven for thinking this image was taken on the seafloor. The common woodlouse is a crustacean – just like lobsters and crabs – and the strange organism it is feasting on could be mistaken for an unusual jellyfish. It is, in fact, not just one creature, but many. These slime moulds, of the *Stemonitis* genus, are single cells who've all come together to reproduce. Seen here is *Stemonitis*'s fruiting body, called a sporangia, which will release spores into the air that can go on to become new, single-celled moulds.

For the woodlouse, the slime mould is a delicious dinner. It contains the carbohydrate cellulose, and is a nice change from the fallen leaves, faeces and wood that the species commonly eat.

BARRY WEBB

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CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

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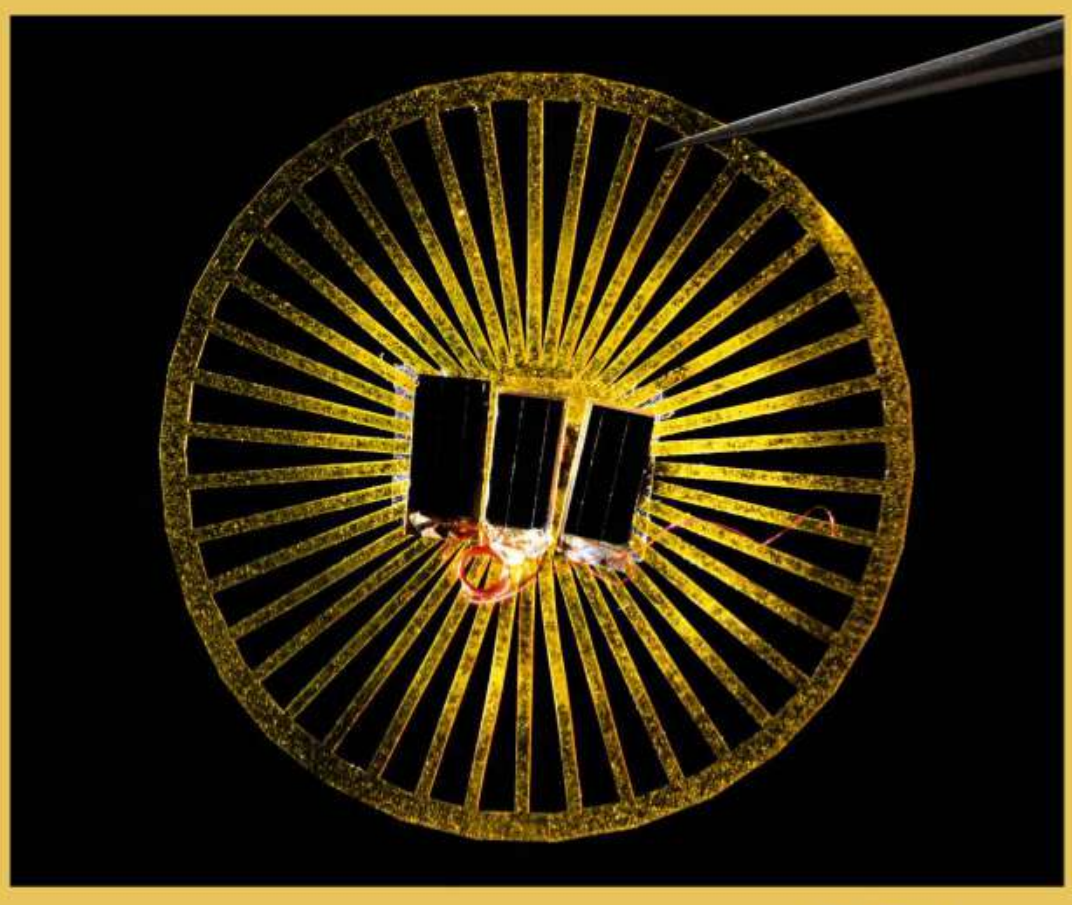
LETTER OF THE MONTH

Just plastic pollution?

I wonder if I am the only one that thinks the distribution of tiny sensors into the environment is not necessarily a good idea? The news story was in your *Lunchtime Genius* newsletter today (17 March). There was no mention in the item of the materials being used to produce these environmental sensors. There is an obvious silicone chip at the heart of the device along with photo cell and capacitor. There is then a small copper wire aerial coated in plastic. I assume the structure is also made of plastic. So, is adding all this silicone, copper and plastic into the environment such a good idea?

Simon Biggs, Dudley



WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a prize bundle from Atom Studios containing a **split wood fibre iPhone case** to keep their phone safe from knocks and bumps, a **flat universal cable,** to allow for versatile charging, and a **screen protector. atomstudios.com**

Nature's art

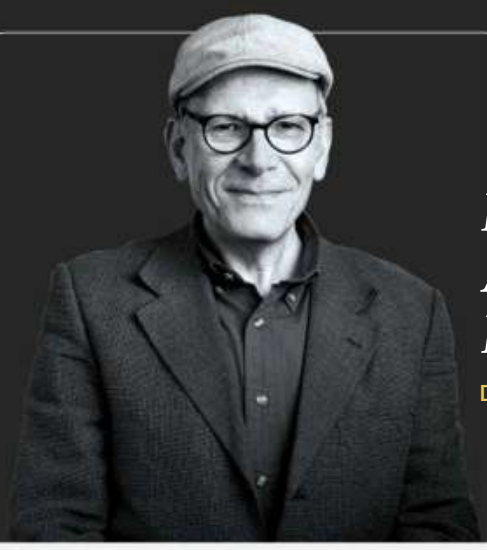
In your June 2021 issue, there was a two-page article regarding microplastics (June 2021, p30). The article influenced the design and content of a sculpture I created for an art show in September 2021. The show's theme was 'our DNA', for which I built an eight-foot double helix emerging from a FedEx box filled with plastic garbage. Bits of plastic are embedded in the DNA's structure, causing its amino acid bonds to separate at the top, unfurl and die. It generated lots of interesting dialogue full of concern about the problem of microplastics. Since the show closed, it's been on display in the Ives Library in downtown New Haven, Connecticut. An enlarged copy of the *BBC Science Focus* microplastic article is displayed next to it.

Mariellen Chapdelaine, on behalf of Joe Fekieta, New Haven, Connecticut

What about tides?

Prof Phil Hart is correct when he says renewable energy from wind and solar power is dependent on the weather (March, p34). But

Joe Fekieta with his DNA sculpture



"DOGS REALLY DO SEEM TO LOOK UP TO THEIR HUMANS IN A WAY SIMILAR TO THE LOVE BETWEEN CHILD AND PARENT"

DR CLIVE WYNNE, P72

Should we sort out the space junk problem before we explore the cosmos?

MARK STONE/UNIVERSIY OF WASHINGTON, MARIELLEN CHAPDELAINE, GETTY IMAGES, DEANNA DENT/ASU

this disregards the scope for energy generation from tidal power. It is not weather dependent and is continuous for 24 hours a day. Why doesn't he mention this in his review of our energy generation problem?

Ivan Dickason, via email

Tidal energy is predictable and consistent where other renewables are not. However, for efficient operations, the water flow speed has to be really quite quick, and that limits the sites around the UK that tidal energy can be deployed. There are a few excellent sites around our coast, and with the right technology they could make a useful contribution to our power needs, but at a much reduced scale to the likes of wind and solar.

Personally, I'm a fan of tidal and tidal barrage technologies as contributors to our energy mix, but they are not the 'big dogs' in the game currently, and unless government policy changes to support their development and deployment, and eventually commercial scale production, they will likely remain somewhat niche for the near to medium term.

Prof Phil Hart, Cranfield University

Space junk

I was both interested and concerned by your article about space junk (March, p15). I believe it raises a bigger question: when we have gone a long way to unbalancing our own planet, how far should we continue this problem into space, with further exploration, before addressing the current buildup of space junk? Using Antarctica as an example, we spent centuries exploring and exploiting the ecosystem before controls were put in place to reduce and to some extent reverse the damage that had already been done. While I appreciate that satellites in Earth orbit have revolutionised many aspects of our lives, is it necessary to litter outer space and other planets with waste before we have cleaned up our own? The financial side of this is a separate aspect, where the money could be beneficially spent closer to home.

Nick Tupper, Surrey

Oops!

In the March issue (p37), we said that shape memory polymers for healing wounds were being developed by Virginia Tech. This should have been credited to Syracuse University.

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ANNUAL SUBSCRIPTION RATES (INC P&P):
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Audit Bureau of Circulations
50,142 (combined, Jan-Dec 2021)

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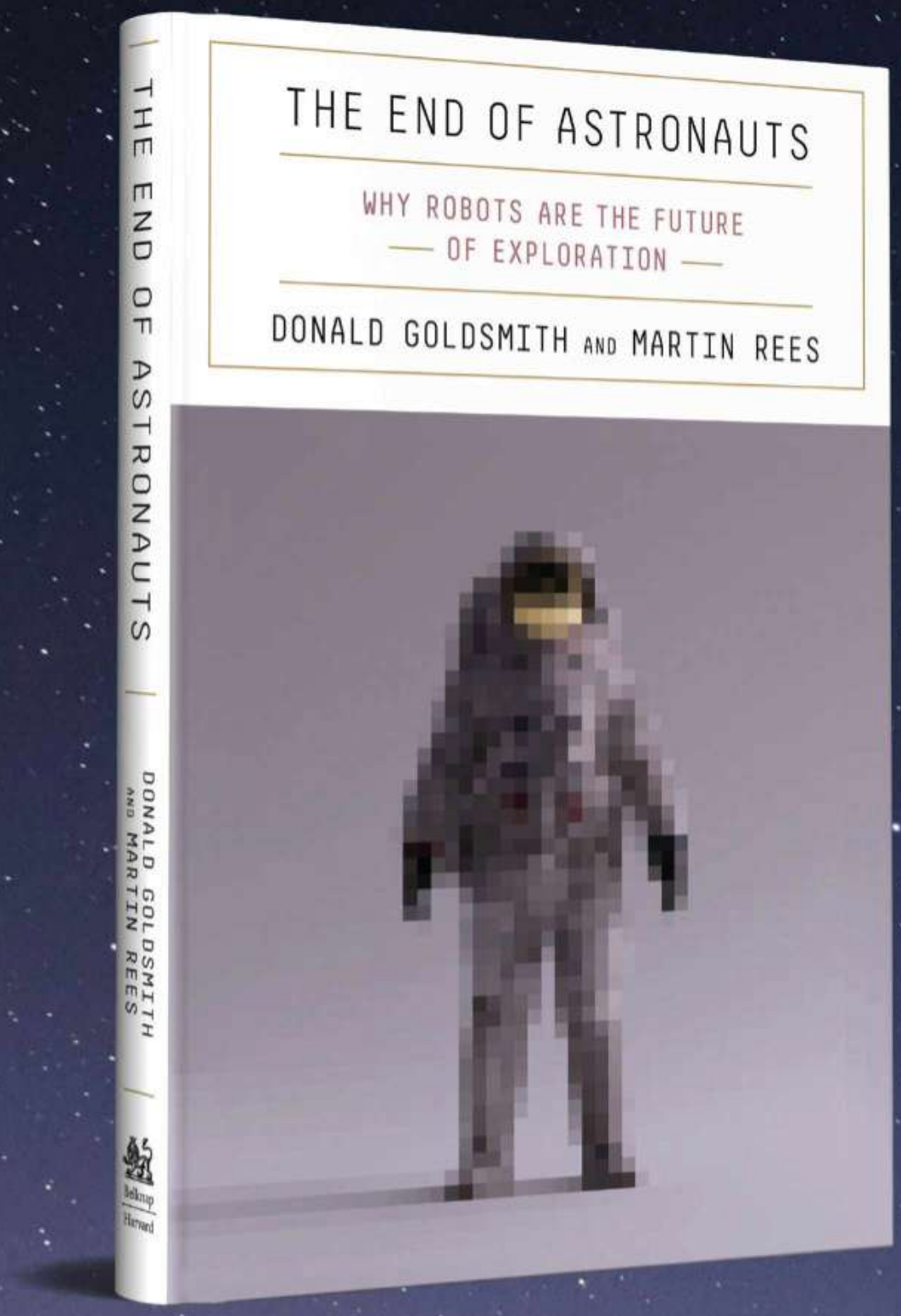
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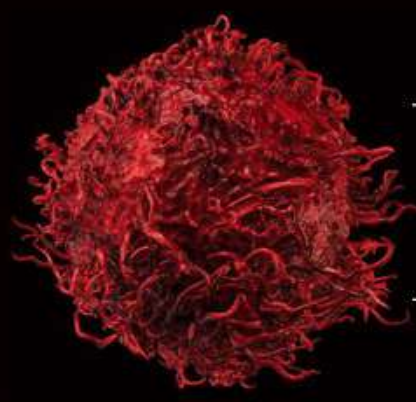

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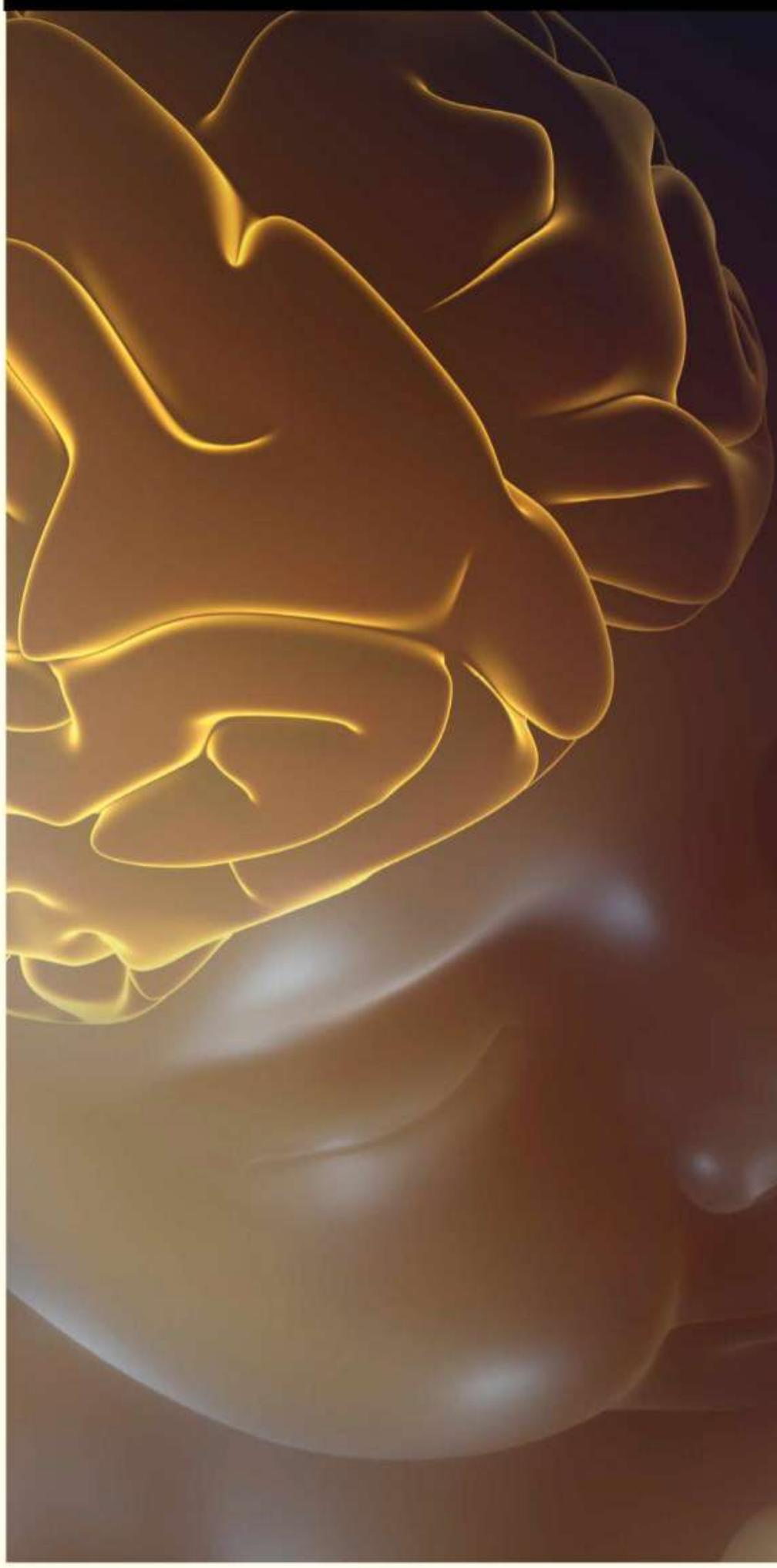

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BRAIN

WORLD-FIRST STUDY CHARTS HOW OUR BRAINS DECLINE AS WE AGE

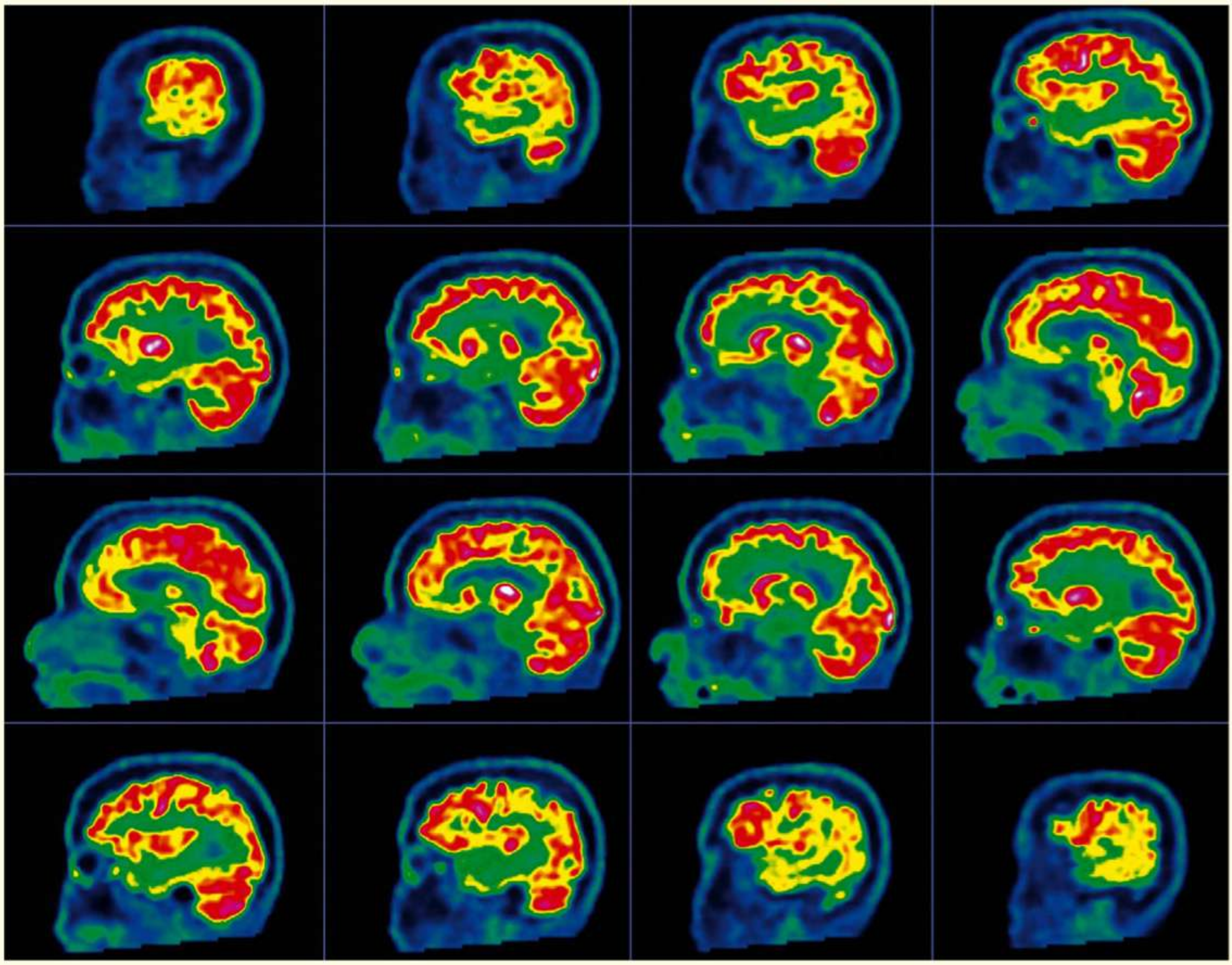
The charts could one day be used as a clinical tool to help track patients' brain development and diagnose neurodevelopmental disorders

The first comprehensive study of how the human brain changes over a lifetime could help doctors to monitor and diagnose neurological conditions such as Alzheimer's.

The study, led by researchers at the University of Cambridge and the University of Philadelphia, has produced a unique set of charts based on brain scans that range from those of a 15-week-old foetus all the way up to a 100-year-old adult.

So far, the researchers have identified a number of developmental milestones, including a rapid growth burst that begins at around 17 weeks after

Ice volcanoes Pluto's landscape may have been shaped by cryovolcanic activity p21 **Brawn, not brains** Early mammals bulked up to survive in a post-dinosaur world p22 **Giant slingshot** NASA tests new device to fling satellites into orbit p24



conception, when the brain is around 10 per cent of its full size. This growth spurt then ends at around three years of age, when the brain has reached around 80 per cent of its full size.

They also found that the volume of grey matter, the part of the brain made up of neurons, peaks at around six years old before beginning to slowly decrease. White matter – the tissue that sends messages between different areas of grey matter – was found to peak at around 29 years old and then decline after we reach 50 years old.

The project began when Dr Richard Bethlehem, of the University of Cambridge, and Dr Jakob Seidlitz, of the University of Pennsylvania, met at a conference. It pulls together data from nearly 125,000 MRI brain scans taken from more than 100 studies worldwide.

"This very much started as a grassroots initiative, essentially between just me and Jakob, at a conference a couple of years ago. We just said to each other, 'wouldn't it be cool if we could pool all these different research studies together to create a reference point or an anchor point for any future work?'" Bethlehem said.

ABOVE Series of brain scans of a woman in her 60s with early-onset Alzheimer's disease

ABOVE RIGHT An Alzheimer's brain (left) compared with a normal brain (right). The Alzheimer's brain is much smaller, due to the loss of nerve cells

"We basically started to reach out to people in our network and also started cold-calling people that had published on specific datasets or specific periods of the lifespan to ask if they wanted to come on board."

The team pieced together the charts by using imaging software to extract data such as the volume of grey and white matter or the thickness of the cortex – the brain's outer covering – from their huge bank of MRI scans. They estimate that the charts, which can be viewed on the open access site **www.brainchart.io**, took around two million hours of computing time to produce.

Although the charts are not ready for use in the clinic, the aim of the project is to map out typical changes that occur in the brain as we age. This data could then be used in much the same way that height and weight charts are used to monitor the development of children. Eventually, they could provide information on how the brain differs in neurological conditions such as Alzheimer's disease, which causes loss of brain tissue.

"If you think about the situation as it exists currently, someone will have a brain scan

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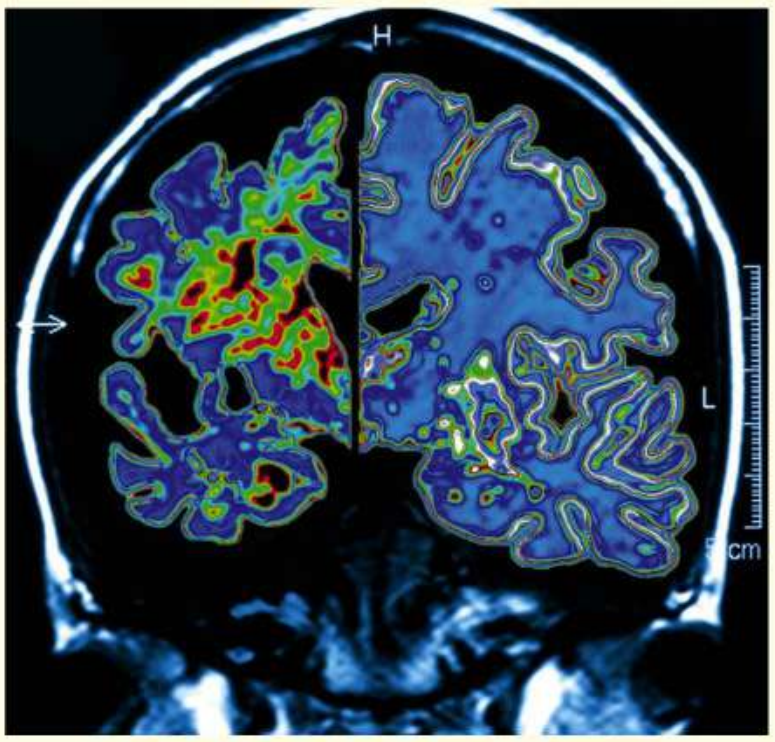


“Although the charts are not ready for use in the clinic, the aim is to map out typical changes that occur in the brain as we age”

because there’s already suspicion that something might be off. And an expert like a radiologist or a neurologist will look at that scan and using all their expertise and knowledge and experience, say, ‘yeah, we can clearly see there’s something not quite right in this scan’. But that’s not a quantitative statement,” said Bethlehem.

“They can’t say it looks atypical by this much relative to where you should be if you’re this age or gender. Hopefully what this tool can provide in the future is something that’s a little bit more quantitative. Something where you can say all this is extreme, but it’s extreme by this much or it’s changed by this much over time.”

The researchers hope to expand the dataset to include more scans taken from under-represented socioeconomic and ethnic groups as well as analysing the current data in finer detail.

“We just scratched the surface with this dataset in terms of defining the milestones in the paper,” said Seidlitz. “In the future, we really hope to hone in on more concrete developmental epochs that have been done in other domains, like in molecular biology, genetics and transcriptomics.”

HEALTH

Huge DNA study reveals new clues about cancer-causing mutations

The findings could lead to better diagnosis and treatments for cancer

A DNA analysis of thousands of tumours taken from NHS patients has shed new light on the genetic causes of cancer and could lead to new targets for treatment.

A team of researchers based at Cambridge University Hospitals and the University of Cambridge analysed the whole-genome sequences of more than 12,000 NHS cancer patients, studying the history of genetic mutations in each patient as the illness progressed.

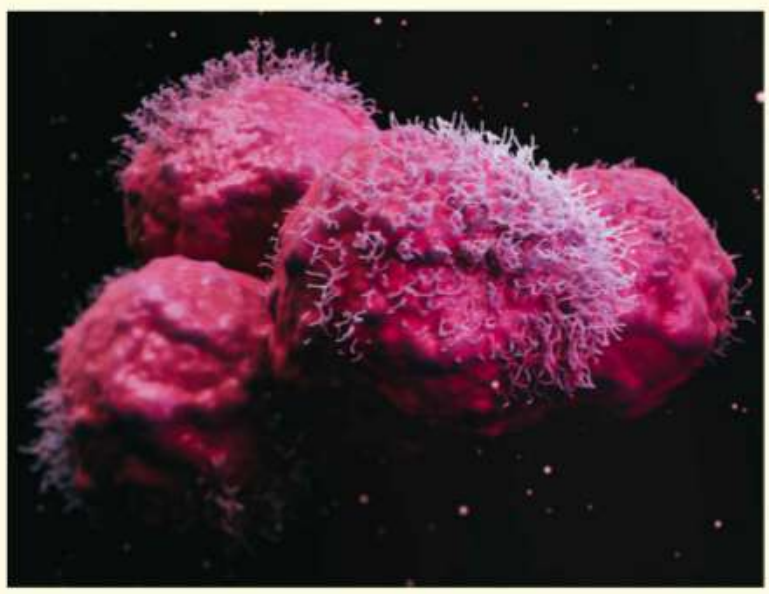
Thanks to the vast size of the data set they had to work with, the researchers were able to detect tell-tale patterns, or mutational signatures, in the DNA of each specific tumour that could provide clues to the patients’ past exposure to environmental causes of cancer such as smoking or UV light. They were also able to pin down 58 previously unidentified mutational signatures.

“The reason it is important to identify mutational signatures is because they are like fingerprints at a crime scene – they help to pinpoint cancer culprits,” said study leader Prof Serena Nik-Zainal, at the University of Cambridge. “Some mutational signatures have clinical or treatment implications – they can highlight abnormalities that may be targeted with specific drugs or may indicate a potential ‘Achilles heel’ in individual cancers.”

The genome data set was provided by the 100,000 Genomes Project, an England-wide clinical research initiative that has sequenced 100,000 whole genomes from more than 85,000 patients affected by rare diseases or cancer.

“With thousands of mutations per cancer, we have unprecedented power to look for commonalities and differences across NHS patients,” said the study’s first author Dr Andrea Degasperi, at the University of Cambridge.

BELOW Cancer cells, like these, contain DNA. DNA signatures in tumours can offer clues to the causes of the cancer



MEDICINE

Sleepiness in Alzheimer's patients is caused by damage to neurons that help them stay awake

The finding could lead to new treatments for those with the disease to help them stay alert

Frequent napping during the day is a common symptom of Alzheimer's and can begin long before any of the memory problems associated with the disease occur. It was widely believed that this was due to patients suffering from periods of disturbed sleep at night and subsequently needing to catch up by taking daytime naps.

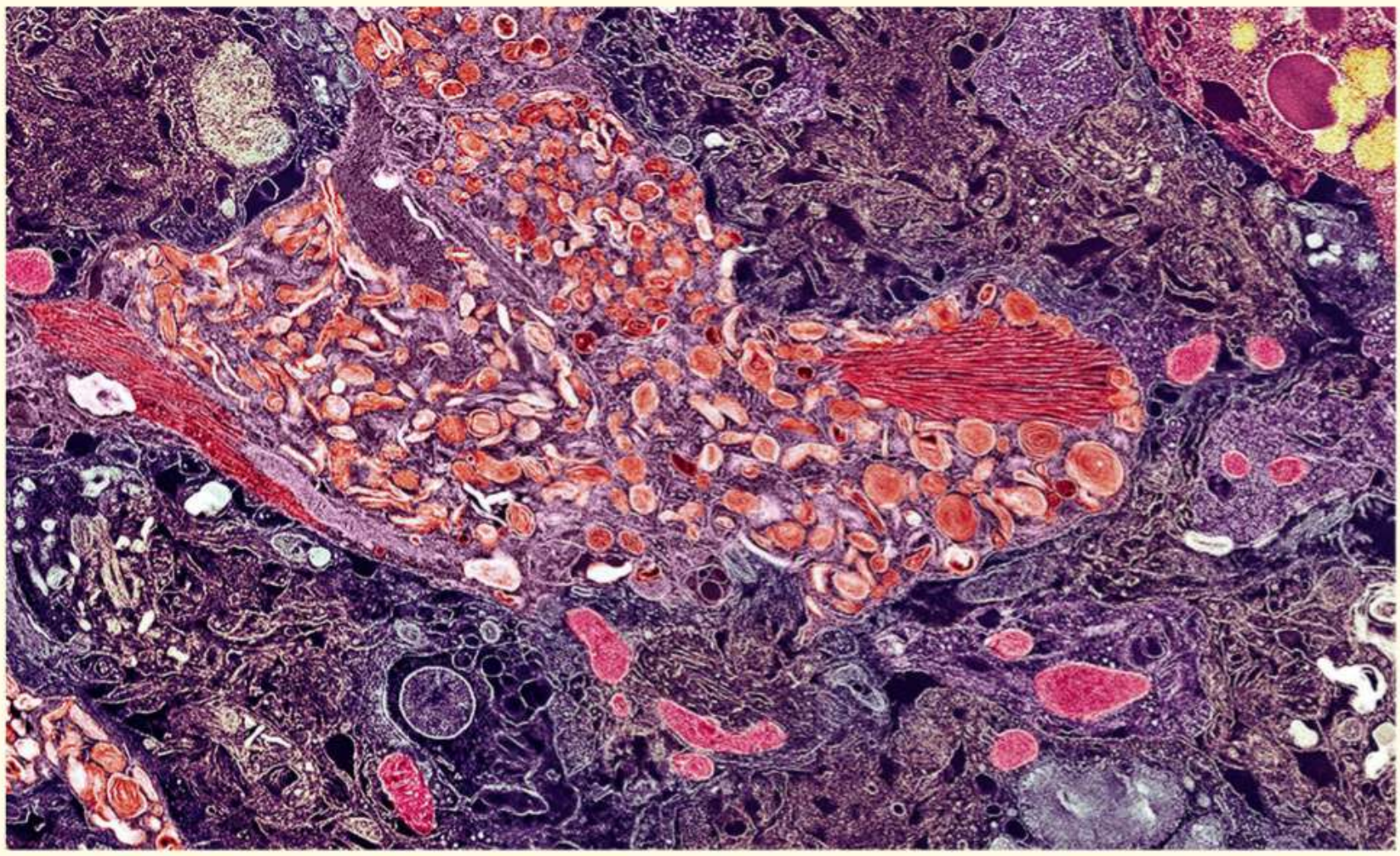
Now, researchers based at the University of California, San Francisco, have discovered that the lethargy and sleepiness experienced by Alzheimer's patients is due to damage to the neurons found in brain areas that promote wakefulness, namely the locus coeruleus, the lateral hypothalamic area and the tuberomammillary nucleus. This damage is caused by the accumulation of tau proteins – small molecules that usually help to stabilise the structure of neurons but break free and clump together in the brains of those with Alzheimer's.

The team made the discovery after studying data taken from patients at the university's Memory and Aging Center, who volunteered to have their sleep monitored with an electroencephalogram (EEG) and donated their brains to be used for research after they died.

The brains of 33 patients with Alzheimer's were compared to 20 who had progressive supranuclear palsy (PSP), a neurodegenerative condition that leaves patients unable to sleep. They found that neurons in the three brain areas are responsible for producing neurotransmitters. In Alzheimer's patients, these neurotransmitters then inhibit other nerve cells, leading to feelings of sleepiness. In PSP patients, they excite them, causing wakefulness.

"You can think of this system as a switch with wake-promoting neurons and sleep-promoting neurons, each tied to neurons controlling circadian rhythms," said Joseph Oh, a medical student and one of the lead authors. "With this post-mortem tissue, we've been able to confirm that this switch, which is known to exist in model animals, also exists in humans and governs our sleep and awake cycles."

The finding could lead to treatments that bump up the 'awake system' in Alzheimer's patients.



In this image, taken by an electron microscope, the pink region in the centre is an amyloid plaque in the brain of an Alzheimer's patient

SCIENCE PHOTO LIBRARY, ANNE BURROWS/DUQUESNE UNIVERSITY

Tissue samples from the orbicularis oris muscles around the mouth, taken from a wolf, domestic dog and human. The samples reveal similarities between the dog and the human

ZOOLOGY

Selectively breeding for puppy-dog eyes may be the reason we can't say no to our canine companions

Thousands of years of breeding has given our canine companions faster facial movements to better communicate with us

A study of facial muscles in dogs and wolves has revealed key anatomical differences that are likely a result of human selective breeding.

Scientists say that the 33,000-year relationship between humans and canines has relied on a reciprocal bond between the two species, which developed through mutual gazing and dogs' ability to 'communicate' with facial expressions similar to ones made by humans.

It's likely that humans selectively bred dogs based on their effectiveness in communicating in this way, which may have led to our furry friends' facial muscles evolving to become faster and more responsive.

The new research, carried out by scientists at Duquesne University in Pittsburgh, compared dogs with wolves and focused on specific muscles called mimetic muscles. These are muscles found in mammals that connect to nerves in the face. They help us communicate our many emotions – pulling our eyebrows into a frown, or our lips into a smile. The facial nerves are often affected by stroke, leading to paralysis of the mimetic muscles.

In humans, the mimetic muscles are made of fibres that enable us to form facial expressions almost instantaneously, said biological anthropologist Dr Anne Burrows, the study's senior author. But while these 'fast-twitch' muscle cells help us to flash a smile the moment someone holds up a camera, they also fatigue quickly, making school picture day a cheek-aching experience.

Mimetic muscle cells with slow-twitch fibres are not as quick to react, but they are better at controlling and maintaining a position.

As facial expressions help us regulate our social interaction and bonds with dogs, Burrows wanted to find out if the mimetic muscles in our canine companions had evolved to enable faster facial movement. Did we selectively breed the puppy-dog eyes?

Compared to samples taken from wolves, dogs' facial muscles had a higher percentage of fast-twitch fibres. This difference likely contributed to dogs' ability to communicate with us, and throughout the domestication process "dog muscles could have evolved to become 'faster', further benefiting communication between dogs and humans," said Burrows. "The classic 'puppy-dog eyes' facial expression is one that dogs make in front of their humans. While we can't know exactly what dogs are thinking when they make this expression, it seems to trigger a caregiving response in humans."

Next, the researchers want to expand their work to cover a variety of dog breeds. "From the very small breeds to the very large – we want to understand any breed differences and whether some breeds use their facial muscles in different ways," said Burrows.

Genetic tests should be widely available so that doctors can personalise patients' treatments more effectively

GETTY IMAGES, NASA/JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY/SOUTHWEST RESEARCH INSTITUTE

HEALTH

Experts call for NHS to provide genetic tests to usher in era of personalised medicine

We must move away from the current "one drug and one dose fits all" model to make treatments safer and more effective

Genetic testing to predict how patients respond to a range of common drugs should be made available as soon as possible, according to a report by the Royal College of Physicians and the British Pharmacological Society.

There can be a huge variation in how people respond to drugs due to differences in their genes. The tests that the experts are calling for are known as pharmacogenomic tests, and can be used to check how safe, effective and side-effect-free more than 40 drugs are in each individual patient by identifying variations in their genes. The authors say that 99 per cent of patients carry at least one of these variations.

While some pharmacogenomic tests – such as one for the chemotherapy drug fluorouracil – are currently available on the NHS, they are not available for most of the drugs on the list, which includes commonly prescribed painkillers, as well as beta blockers and antidepressants.

One striking example is codeine, a commonly prescribed painkiller. Around 8 per cent of people in the UK lack the gene that codeine acts on and so don't experience any pain relief from taking it.

"The UK is a world leader in genomic medicine, and the implementation of a wider range of pharmacogenomic tests would further demonstrate UK leadership," said Prof Sir Munir Pirmohamed, David Weatherall Chair of Medicine at the University of Liverpool, and Chair of the report's working party.

"Today we are calling on the government and the health service to ensure that patients across the UK are offered these tests where there is evidence to show their utility. For patients, this will mean the medicines they take are more likely to work and will be safer.

"In the 21st Century, we need to move away from the paradigm of 'one drug and one dose fits all' to a more personalised approach where patients are given the right drug at the right dose to improve the effectiveness and safety of medicines," he added.

SPACE

Giant ice volcanoes may have sculpted Pluto's mysterious landscape

Cryovolcanic activity was ongoing beneath the dwarf planet's surface in the recent geological past, data from NASA's New Horizons mission suggests

A series of peaks, domes and troughs found on Pluto's undulating surface may have been created by icy material being pushed up to the surface by cryovolcanic activity, analysis of data collected by NASA's New Horizons mission has found.

The so-called hummocky terrain runs across Sputnik Planitia, an area found southwest of Pluto's icy heart, and consists of a network of icy formations ranging from one to seven kilometres tall and 30 to 100 kilometres across.

"The particular structures we studied are unique to Pluto, at least so far," said lead author Dr Kelsi Singer, New Horizons deputy project scientist from the Southwest Research Institute, Boulder, Colorado. "Rather than erosion or other geologic processes, cryovolcanic activity appears to have extruded large amounts of material onto Pluto's exterior and resurfaced an entire region of the hemisphere [that] New Horizons saw up close."

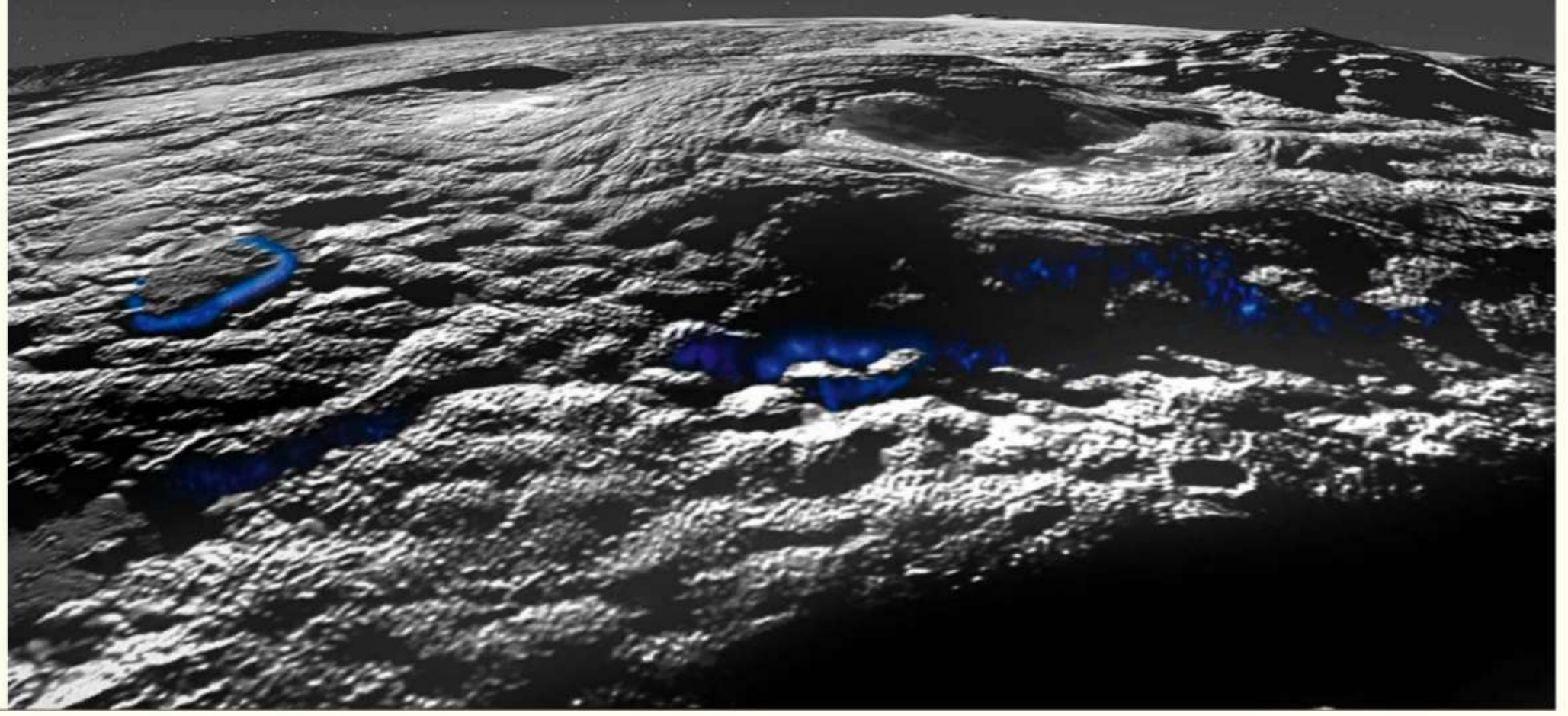
BELOW The blue regions illustrate icy volcanic action on Pluto. The ring to the left is a growing volcanic dome, while the areas to the right show general flows of material to the surface

The researchers believe this region of Pluto is relatively young, geologically speaking, as there are few craters – meaning it hasn't had much time to have been hit by asteroids. Because of this, and the fact that the formations contain large amounts of material, the researchers say it is possible that Pluto's interior structure retained heat into the relatively recent past, enabling materials rich in water ice to be deposited onto the surface.

The structures could've been created by water rising up from beneath the surface and being rapidly frozen by the dwarf planet's extremely low temperatures and atmospheric pressures, the researchers say.

This could've occurred if the material had a toothpaste-like consistency, or flowed in a similar way to how solid ice glaciers flow on Earth, or consisted of a frozen shell covering material that was still able to flow underneath.

"One of the benefits of exploring new places in the Solar System is that we find things we weren't expecting," said Singer. "These giant, strange-looking cryovolcanoes observed by New Horizons are a great example of how we are expanding our knowledge of volcanic processes and geological activity on icy worlds."



MAMMALS

Prehistoric mammals bulked up to survive the tumultuous world after the dinosaurs

Brawn, not brains, allowed our ancestors to flourish after the asteroid hit

In the first 10 million years after the extinction of the dinosaurs, mammals developed bigger bodies to help cope with the radical changes that were occurring on Earth, researchers at the University of Edinburgh have found.

To make the discovery, the team CT-scanned a collection of complete skulls and skeletons of mammals that lived in the badlands of northwestern New Mexico immediately after the mass extinction of dinosaurs.

It was previously thought that mammals' relative brain sizes – the size of their brains in relation to their bodies – increased following the catastrophic asteroid impact that ended the reign of dinosaurs 66 million years ago. The theory being that bigger brains would have allowed the prehistoric mammals to take advantage of any new opportunities that opened up as the dinosaurs died out.

However, the researchers' findings show that the relative brain sizes actually *decreased* at first, due to early mammals' rapid increase in body size.

Results of scans also suggest the animals relied heavily on their sense of smell, and that their vision and other senses were far less developed.

"Large brains are expensive to maintain and, if not necessary to acquire resources, would have probably been detrimental for the survival of early placental mammals in the chaos and upheaval after the asteroid impact," said lead researcher Dr Ornella Bertrand.

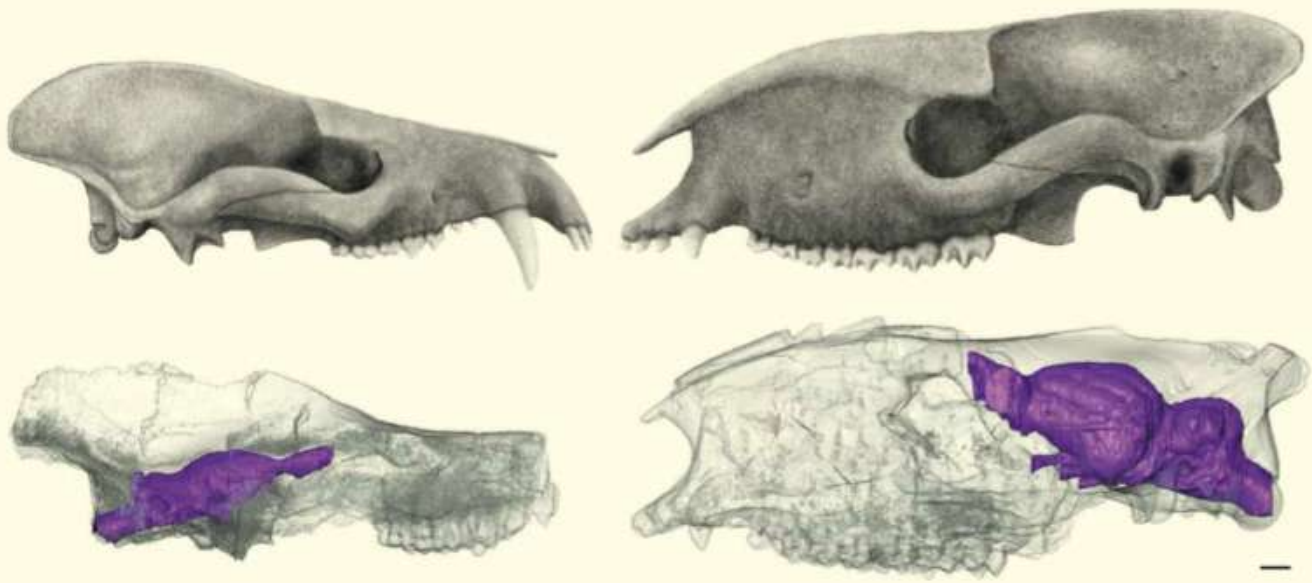
It wasn't until around 10 million years after the extinction of the dinosaurs that early members of modern mammal groups, such as primates, began to develop larger brains and a complex range of senses and motor skills.

"The mammals that usurped the dinosaurs were fairly dim-witted, and only millions of years later did many types of mammals develop bigger brains as they were competing with each other to form new ecosystems," added senior author Prof Steve Brusatte.

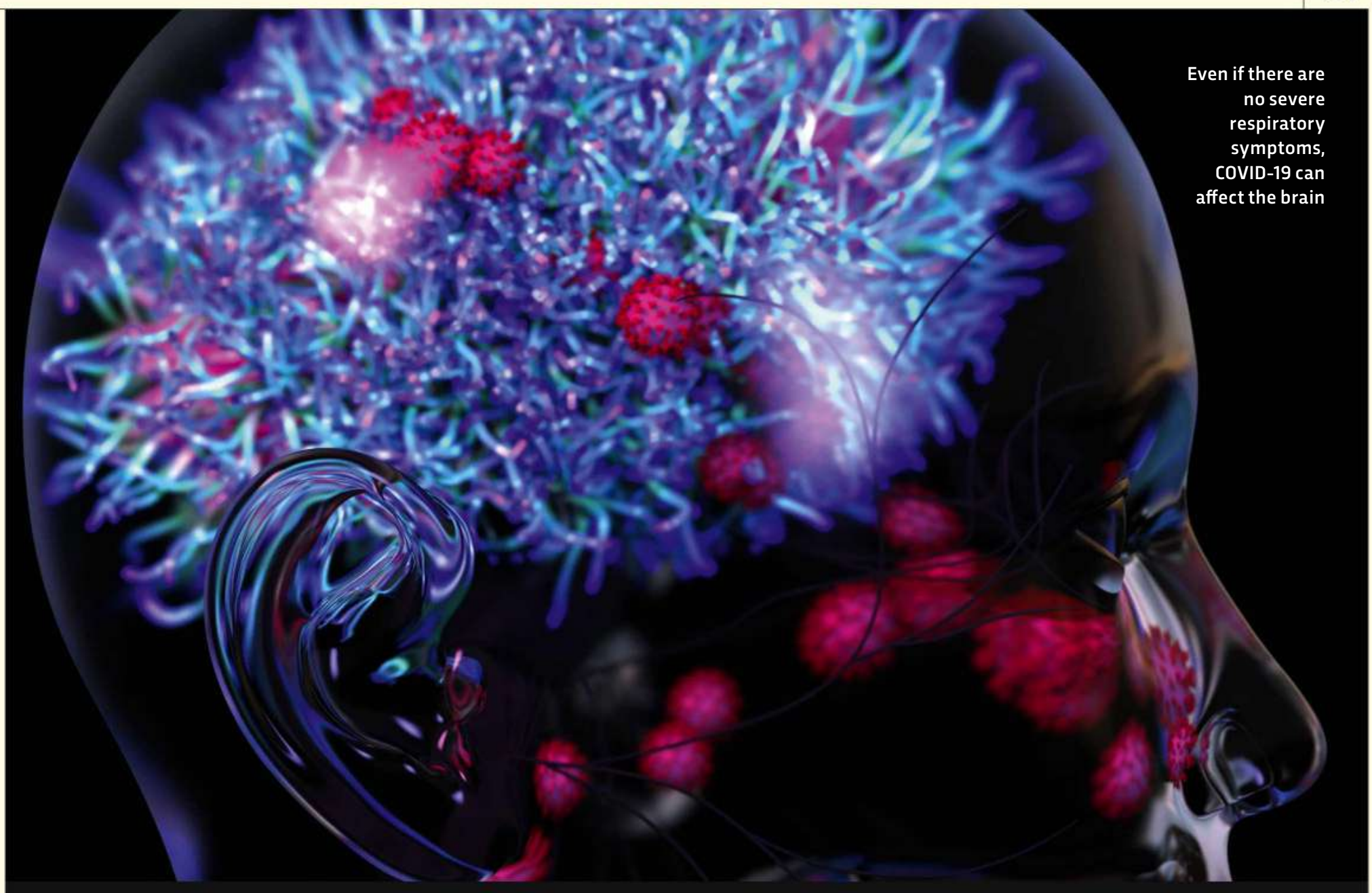
RIGHT Dr Ornella Bertrand with the fossilised skulls of early mammals

BELOW CT scans of the Palaeocene mammal *Arctocyon* (left) and the later Eocene mammal *Hyrachyus* (right) with the purple areas showing where the brain would've been located

"The mammals that usurped the dinosaurs were fairly dim-witted"



ORNELLA BERTRAND/SARAH SHELLEY X2, GETTY IMAGES



Even if there are no severe respiratory symptoms, COVID-19 can affect the brain

HEALTH

COVID-19 can have long-term impacts on the brain

According to a study on non-human primates, effects of SARS-CoV-2 infection on the brain include reduced oxygen flow, neuron damage and bleeding

It has long been noted that COVID-19 patients can suffer from a wide range of neurological symptoms such as headaches, confusion and loss of taste and smell.

They are often the first symptoms of SARS-CoV-2 infection to arise and can be severe and long-lasting. They also occur indiscriminately in patients, regardless of age or the presence of other medical conditions. But little is known about exactly how the disease affects the brain and central nervous system.

Now, a group of researchers at Tulane University in New Orleans, USA, have published the first comprehensive study investigating the effects of COVID-19 in the brains of non-human primates.

They found that subjects infected with SARS-CoV-2 showed signs of severe inflammation and injury, indicating a reduction in blood or oxygen flow into the brain, neuron damage and small areas of bleeding.

Moreover, this type of damage was also seen in subjects that did not show signs of severe respiratory disease following infection from the virus, which may provide insight into the range of neurological symptoms associated with long COVID, the researchers say.

"Because the subjects didn't experience significant respiratory symptoms, no one expected them to have the severity of disease that we found in the brain," said lead author Dr Tracy Fischer, lead investigator and associate professor of microbiology and immunology at the Tulane National Primate Research Center. "But the findings were distinct and profound, and undeniably a result of the infection."

The study was launched in the spring of 2020 and saw the researchers studying brain tissue samples taken from four rhesus macaques and four African green monkeys that had been infected with SARS-CoV-2, along with samples from two uninfected animals of each species that were used as controls.

The findings also mirror those of post-mortem studies carried out in humans who have died of COVID-19, suggesting that rhesus macaques and African green monkeys can accurately act as a model for studying how humans experience the disease, the researchers say.

SPACE

NASA to test giant slingshot designed to fling satellites into orbit

NASA has teamed up with private spaceflight company SpinLaunch to trial a unique system designed to send satellites into space using a slingshot-like launcher.

The system works by attaching a rocket payload onto one end of a giant spinning arm powered by electric motors, accelerating it to high speeds and then flinging it out into space.

As it is housed in a vacuum chamber with next to no air resistance, the arm can be accelerated to around 450 rotations per minute, allowing it to launch the payload through a chute mounted on the top of the system at speeds of up to 8,000km/h – enough to send it into low Earth orbit.

In October last year, the SpinLaunch team carried out a successful test run of a scaled-down prototype of the system, the A33 Magnetic Orbital Accelerator, at Spaceport America in New Mexico.

The team plans to further test the A33 with payloads fitted with boosters that start firing when they reach the upper atmosphere, which will allow the satellites to be manoeuvred into the desired position once they are in orbit.

Work has now started on the L100 Magnetic Orbital Accelerator, a system based on the A33 only much larger. It is scheduled to be fully operational by 2025.

1

2

3

SPINLAUNCH X4

1 The team plans to fit the three-metre-long rockets launched by the L100 (shown here in a CGI render) with internal boosters that kick in when they reach the upper atmosphere, allowing them to be manoeuvred into the desired position.

2 The central chamber of the L100 (shown here in a CGI render) will be kept in near-vacuum conditions to make sure air resistance is kept to a minimum as the payload is accelerated.

3 A three-metre rocket being launched from the prototype A33 during a test flight at Spaceport America in October 2021. The rocket made it several thousand metres into the air, despite the system only running at about 20 per cent of its full power. The rocket can be seen as a faint speck near the top of the photograph.

4 The researchers say that the system will be more cost effective and environmentally friendly than current launch systems, as it does not require rockets to carry large amounts of fuel to take them up into the atmosphere.

4

NASA/XS

PROF CHRIS BAIL
Social scientist

Horizons

How to build the future of social media

At the Polarization Lab in North Carolina, multidisciplinary researchers – including social scientists, statisticians and computer scientists – are breaking apart the social media status quo to rebuild it, one peer-reviewed brick at a time

WHAT'S WRONG WITH SOCIAL MEDIA PLATFORMS AS WE KNOW THEM?

We've just accepted that how social media is now, is how it's always going to be. But Facebook started as a site for college students to rate each other's physical attractiveness. Instagram was essentially a way to organise alcohol-based gatherings, and was originally called Bourbon. Why should we accept these platforms that were designed for sophomoric purposes as the status quo, as the inevitable?

Meanwhile, incivility, hatred and outrage have never been higher. There's evidence that suggests social media is contributing to all those things. It's certainly not the only contributor, but there's growing consensus that it's a major player.

[But before we make changes] we need to understand how platforms shape human behaviour. That's what prompted us to say, "Okay, we need a social media platform for scientific research."

IS YOUR SOCIAL MEDIA SITE BASED ON ANY PLATFORM IN PARTICULAR, OR IS IT COMPLETELY NEW?

We're building our platform for two purposes. One is to simulate existing sites, like Twitter and Facebook. When you're exploring interventions that could decrease positive behaviour, it's dangerous to do it in the wild. So, we need a testing ground – in the world of computer science, we call it a sandbox. It's where we start to learn how to play.

But the thing that we're much more excited about is using our site to explore the possibilities for social media more systematically.

WHAT POSSIBILITIES ARE THERE?

There are many other models that we could explore. Tech leaders say the point of social media is to connect people. That's Mark Zuckerberg's stated mission for Facebook.

On the one hand, that's admirable. You can connect the world in largely positive ways – people in Ukraine can fundraise internationally, for example.

But we don't know what connecting to that many people does to the human brain. The British anthropologist Prof Robin Dunbar famously discovered that we struggle to maintain meaningful relationships with more than 150 people. Promoting connection *ad infinitum* might create shallow, meaningless connections instead of the deeper ones that give the social cohesion that sustains civil society.

CAN YOU GIVE ME AN EXAMPLE OF HOW YOUR SOCIAL MEDIA SITE HAS BEEN USED?

There's an interesting debate going on among people who study social media about how anonymity might shape our behaviour. People tend to say things on social media that they would never say in real life, especially when they are anonymous, because there are no consequences.

But there's another side of anonymity that's less well understood. Imagine that I am a Republican in the United States and I see all this evidence that voter fraud didn't happen, or maybe I'm sceptical of former President Trump's claims that voter fraud happened. If I go on to Twitter and announce my view to my Republican followers, I might get attacked by people on my side. But if I'm anonymous, I might throw out the idea.

In other words, anonymity gives us the ability to explore unpopular ideas, and allows us to focus on ideas instead of the identities of the people who are voicing them. We wanted to know if anonymity could prevent some of the tribalist tendencies that we see on social media.

But we as researchers can't walk into Facebook and say, "Hey, could we please make 1,200 of your users anonymous for two weeks?"

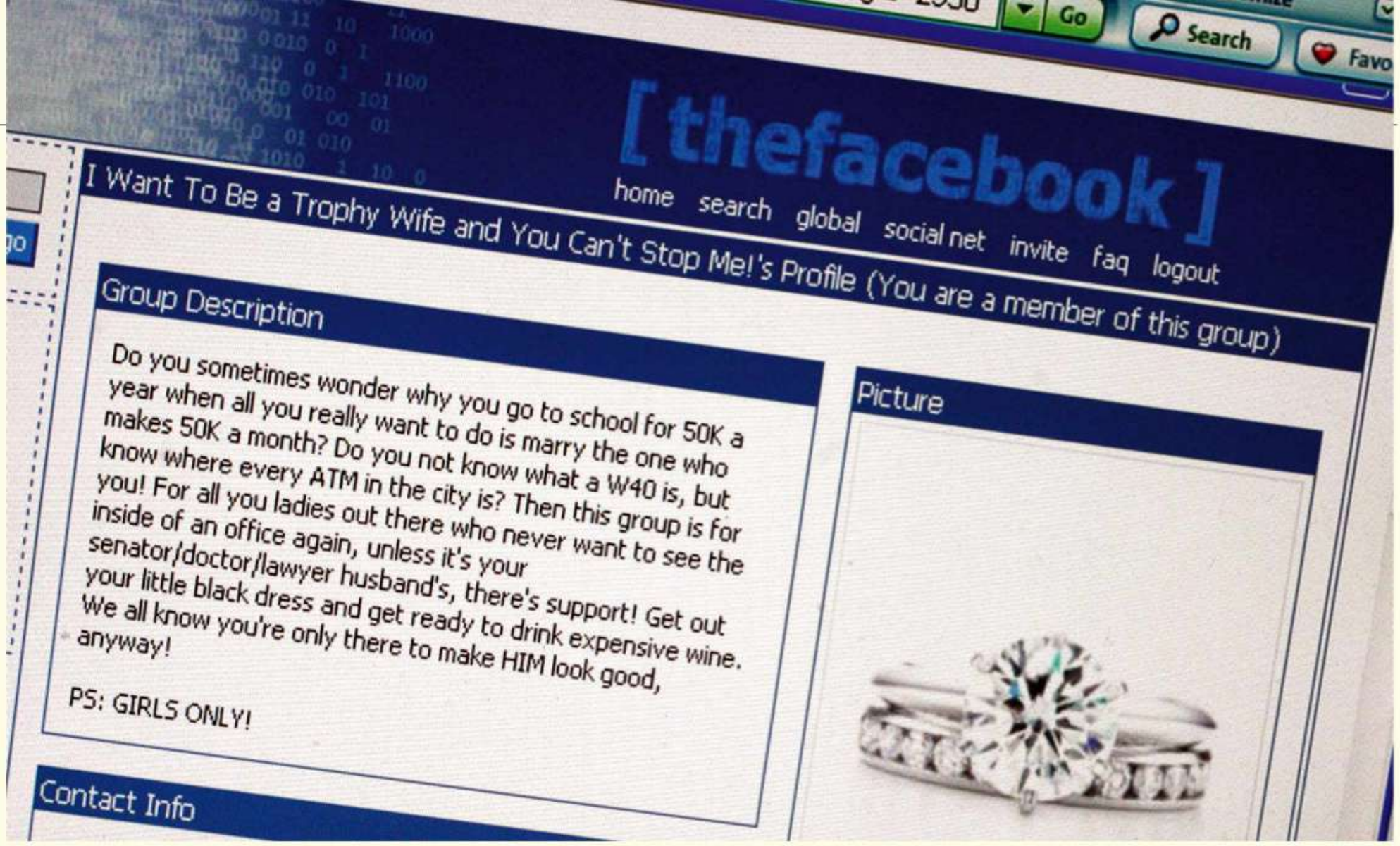
Not only is it logistically impossible, it would upset users. It probably couldn't be done with high scientific validity. But on our platform, we connected people to talk anonymously about politics – either immigration or gun control – with a member of the other party in an anonymous context.

Half of our research team thought it would be bad and would lead to hateful statements and abusive rhetoric. While there were several conversations on our platform that got so toxic that we had to shut them down, the vast majority were extraordinarily productive. People actually exhibited less polarisation when they chatted with someone from the other party anonymously.

This is not the be-all and end-all study. The implication is not that Facebook should become anonymous tomorrow. But it raises the question, should platforms create a space for anonymous conversation under carefully controlled settings? Maybe.

AND IT COULD BE USED BY ACADEMICS AROUND THE WORLD?

The idea is to make a platform that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home search global social net invite faq logout
I Want To Be a Trophy Wife and You Can't Stop Me!'s Profile (You are a member of this group)
Group Description
Do you sometimes wonder why you go to school for 50K a year when all you really want to do is marry the one who makes 50K a month? Do you not know what a W40 is, but know where every ATM in the city is? Then this group is for you! For all you ladies out there who never want to see the inside of an office again, unless it's your senator/doctor/lawyer husband's, there's support! Get out your little black dress and get ready to drink expensive wine. We all know you're only there to make HIM look good, anyway!
PS: GIRLS ONLY!
Picture
Contact Info
Search

Facebook offers opportunities to connect, but we don't know if it could be harmful to link up with so many people

GETTY IMAGES

"Social media could become this experience of what we all agree on, instead of this dumpster fire of outrage it's become"

anyone could alter to suit their research. At the Polarization Lab, we're focused on politics, but there are so many other really important issues out there. Researchers in public health could use it to study the effects of social media on mental health, or the impact on vaccine uptake.

Social media's algorithms are often blamed for the polarisation online. Most social media platforms are explicitly designed to spread information as far as possible. So if you are a software engineer, what you're going to do is look for characteristics of messages that spread, and train your algorithm to identify and boost content with those characteristics.

People ask if the algorithm is good or not. Instead, we should ask what a good algorithm would look like. Social science could offer a number of designs for algorithms that would promote better behaviour. What if, instead of boosting divisive content, an algorithm boosts unifying content? Instead of boosting what one party says when it appeals to its supporters, why not boost content that both sides of the political debate like? In that way, social media could create consensus instead of creating division.

It could go further than politics. You could do this across racial and ethnic groups, across genders. All of a sudden, social media could become this experience of what we all agree on, or all find interesting, important or useful. Instead of this, excuse my language, dumpster fire of outrage and sensationalism that it's become.

IT SEEMS LIKE THIS KIND OF RESEARCH SHOULD HAVE BEEN DONE WHEN SOCIAL MEDIA PLATFORMS FIRST STARTED BECOMING POPULAR...

For a long time, social scientists like me struggled to get a lot of data. Compare us to physicists who have massive particle colliders, or biologists who can look at the entire human genome. We were usually studying a couple of dozen people. And that fundamentally limits what kind of questions you can ask.

The advent of social media, the mass digitisation of human language and the various digital traces that human beings leave behind meant we were finally able to do really exciting analyses of large groups of people. People were calling it the Golden Age of social science. And in some ways it was. Many of us were fortunate enough to get data from places like Facebook and do some foundational research.

The trouble started about four years ago when academic research became deeply embedded in controversies at Facebook and other platforms. Most notable was the Cambridge Analytica case, where a massive amount of data about people was used, largely without their consent, to serve political ends.

The idea that scientific research could give nefarious actors access to potentially powerful information led tech companies to stop sharing their data [with academics].

PROF CHRIS BAIL
Chris is the director of the Polarization Lab at Duke University and a professor of sociology and public policy.

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REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Peat-free compost | Skin microbiome | W boson

REVIEW

PEAT-FREE COMPOST: IS IT REALLY BETTER FOR THE ENVIRONMENT?

Compost containing peat is due to be banned for UK gardeners. What's the debate around ending peat sales, and are there any alternatives?

"Peatlands cover around 3 per cent of the planet's surface but hold twice as much soil carbon as all the world's forests"

Visit the BBC's Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

For years, environmentalists have been pushing for a ban on the sales of peat in the UK, citing the peat supply chain's high carbon emissions, as well as the ecological importance of the environment it comes from. This may now soon happen, with the UK government announcing in December plans to ban sales of peat to gardeners by 2024. But some campaigners say this is still not soon enough, while others warn that rapidly scaling up the supply of sustainable alternatives to peat may be a challenge.

WHAT IS PEAT AND WHY IS IT USED FOR GARDENING?

Peat is a soil made of decaying plant matter and is formed in peatlands, a waterlogged wetland habitat. Peatlands take thousands of years to form, as peat grows at a rate of just one centimetre every 10 years.

"When we take it out of peat bogs and use it, we're depleting it far, far faster than it can be replenished," says Ali Morse, a peat and water policy expert at The Wildlife Trusts. "It's effectively a non-renewable resource."

Peatlands provide vital ecosystem services: they decrease flood risk and supply drinking water, as well as supporting rare wildlife. They also store a lot of carbon. Peatlands cover around 3 per cent of the planet's surface but hold twice as much soil carbon as all the world's forests. This carbon is released into the atmosphere when peatlands dry out, or when peat is extracted for use in horticulture.

"If we don't take good care of peatland habitats across the world, we are really going to struggle to prevent runaway climate change," says Morse.

Peat's ability to hold onto water and nutrients have made it prized by gardeners as a growing medium. While its use in horticulture has been declining, nearly a third of all compost sold in the UK in 2021 was still peat, according to the Horticultural Trade Association.

WHY IS PEAT COMPOST BEING BANNED?

In December 2021, the government published a consultation proposing a ban on sales of peat to gardeners in England and Wales by 2024. "By ending the retail sale of peat in horticulture, we will be protecting our vulnerable peatlands and helping to prevent climate change," it said.

Peatlands are the UK's largest stores of carbon, says Prof Alistair Griffiths, director of science at the Royal Horticultural Society (RHS). The proposed ban will help the government deliver on its net zero strategy, he adds.

The UK government has previously set several targets to stop the use of peat. In 2011, it set a voluntary target for compost retailers to end sales of peat by 2020, which was missed. Another voluntary target to end professional use for growing fruit, vegetables and plants by 2030 is also off track, says Morse.

"Part of the reason that these voluntary targets have been unsuccessful is they just don't send a strong enough steer to the industry," says Morse. "There is a need to invest in research and development in order to find appropriate replacements for peat. A proper government-sanctioned end to sales is needed to drive that investment."

HOW CAN I BE SURE I'M BUYING PEAT-FREE COMPOST?

There are a variety of different peat-free composts that aim to emulate the properties of peat and support healthy plants. Some are made from renewable organic materials such as bark, wood

LEFT Peat bogs, like this one in the Scottish Highlands, hold onto water and support rare wildlife

BELOW Peatlands take thousands of years to form and cannot quickly replenish once harvested

GETTY IMAGES X2

Harvesting of turf and peat in the Irish countryside

chips, wool or coconut fibre (coir), but they can also be made from organic waste, such as household garden waste collections.

Griffiths notes that many peat-free alternatives were not good quality when they were initially rolled out some years ago, and this belief seems to have stuck with many gardeners. However, research has vastly improved the quality of peat-free alternatives, which can now in some cases provide better results than peat, he says.

But it is not always clear whether or not compost contains peat, says Morse. "There are composites available which contain peat and they will say things like 'natural material' or 'organic', which of course peat is," she says. "So you explicitly need it to say 'peat-free' in order to be confident that that is the case."

Griffiths recommends asking your retailer whether you are using the right peat-free compost for the right purpose. "If you are mulching your beds, look to use barks or other mulches. Or even better, compost at home and use your own compost on your beds," he says. Simply asking your retailer for peat-free options can help demonstrate consumer demand.

HOW MUCH OF AN IMPACT WILL SWITCHING TO PEAT-FREE COMPOST MAKE?

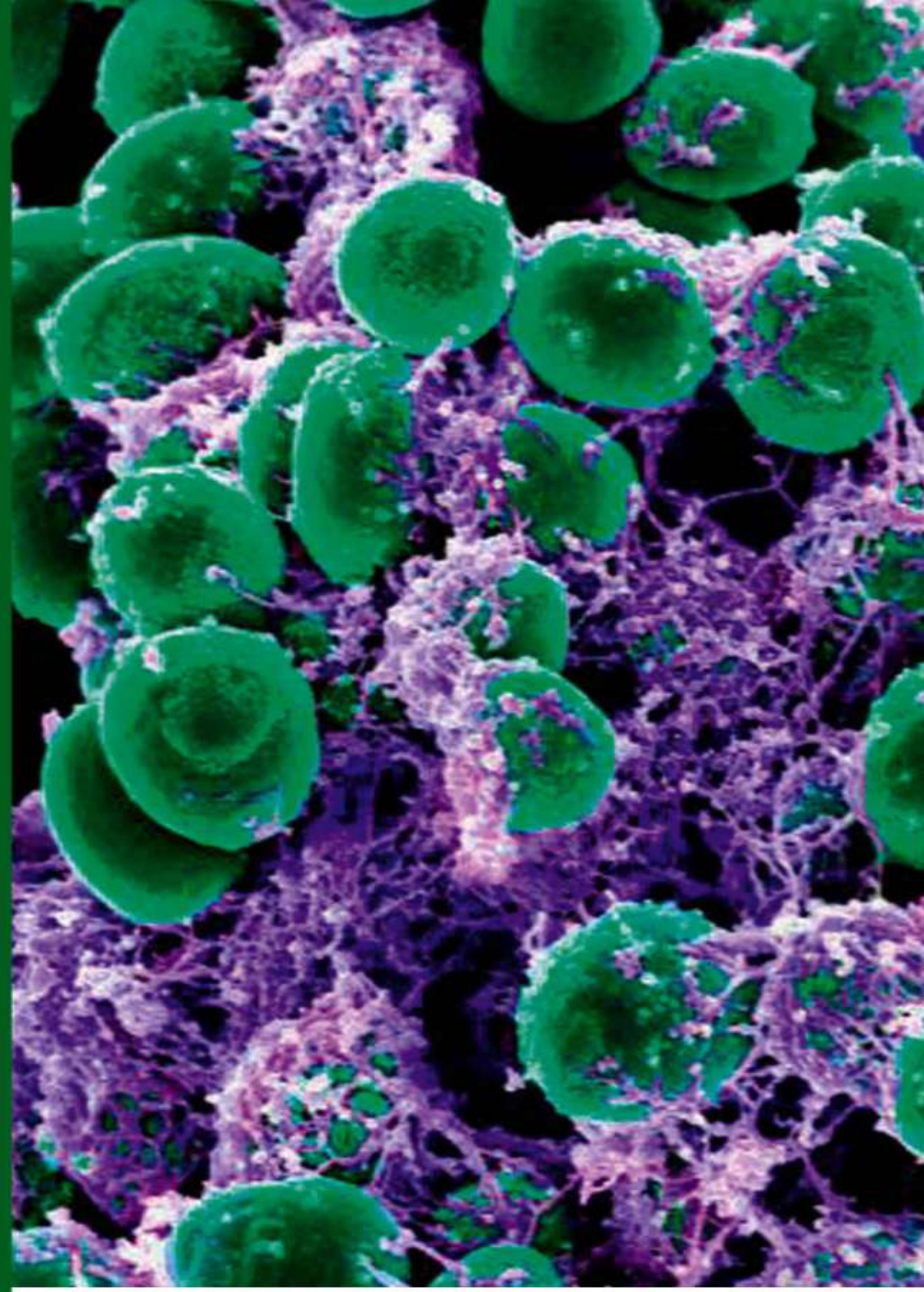
Damaged peatlands are responsible for almost 5 per cent of human-made CO_2 emissions. "Switching to peat-free and not using peat, alongside peatland restoration, has great potential to significantly reduce emissions," says Griffiths, adding that restored peatlands also have the potential to draw down and store more carbon. "By switching to peat-free compost, the UK can set a leading example to the rest of the world," he adds.

The Wildlife Trusts says that even waiting until 2024 is too long, and is pushing for an immediate ban on peat-based compost. It has calculated that waiting another two years would generate another 1.5 million tonnes of CO_2, equivalent to the annual emissions of 214,000 UK residents.

—

by **JOCELYN TIMPERLEY**

Jocelyn is a freelance climate and science journalist.

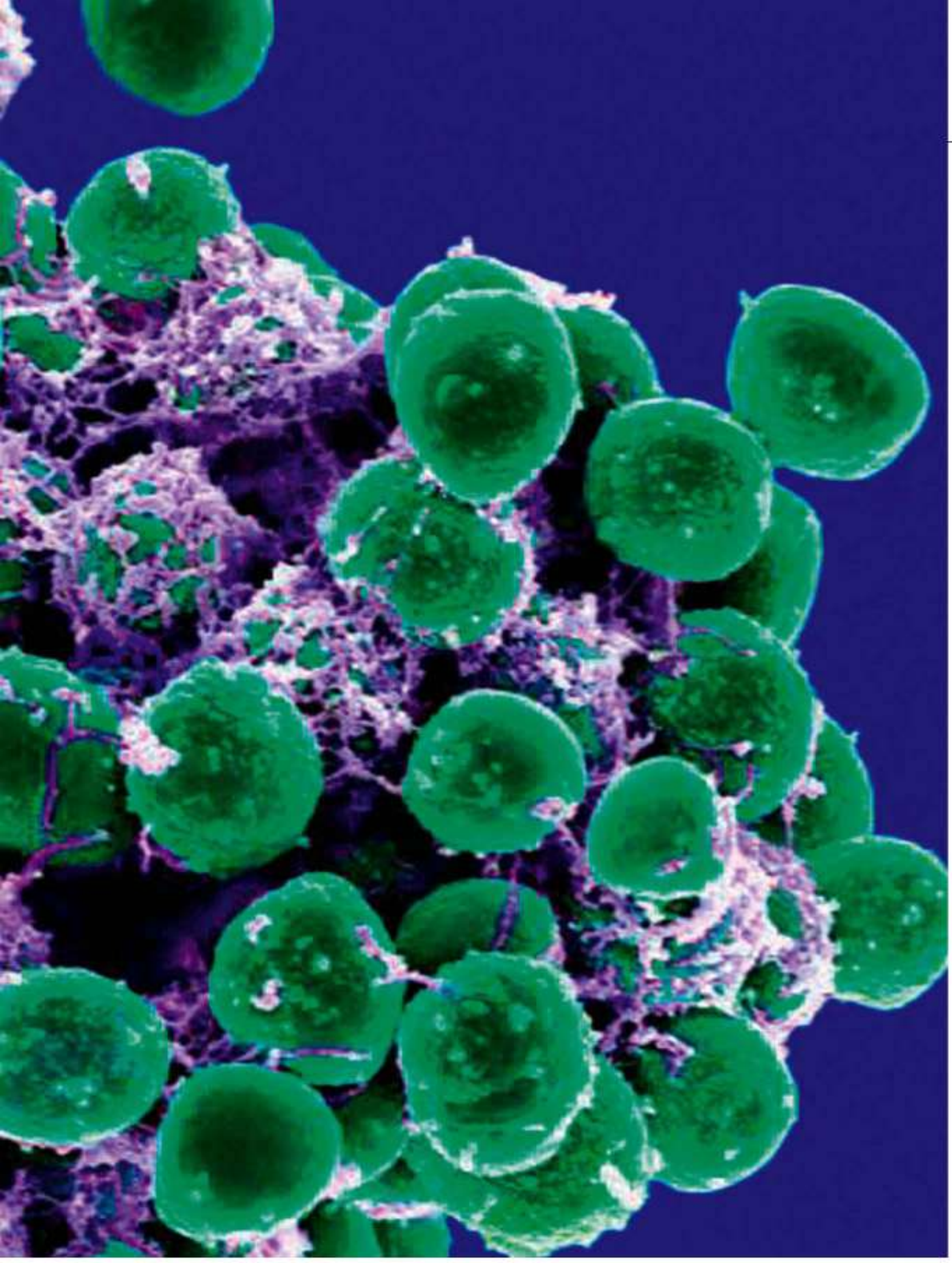


ANALYSIS

MICROBIOME-FRIENDLY SKINCARE: DOES IT WORK?

More and more hygiene products are claiming to be 'microbiome friendly' but how important is our skin microbiome, and do we need to look after it?

At the moment we're born, each of us is seeded with trillions of bacteria cells that live and thrive on our skin. These cells form what's known as our skin microbiome. The exact makeup of each person's microbiome is as unique as a fingerprint. As we go through life meeting new people, interacting with environments, adopting different lifestyles, and changing with age, so too does the diversity and health of this microbiome.



ALAMY X2

ABOVE *Staphylococcus epidermidis* bacteria are part of the normal skin microbiome in humans

"The skin microbiome is a natural ecosystem of bacteria that live on the skin," explains cosmetic doctor and skin specialist Dr Martin Kinsella. "It works to guard the skin against harmful pathogens to the point where a well-functioning skin microbiome is the foundation of a healthy immune system."

As the microbes colonise our skin, they flourish by feeding on the salt, water and oil (sebum) we produce naturally. When a pathogen comes into contact with a flourishing microbiome, it's prevented from colonising the skin by being crowded out. Our microbiome produces antimicrobial compounds and nutrients that act as a form of protection.

Indicative of this protective nature, studies have found links between babies born via caesarean section, meaning they don't come into contact with vaginal microbes during birth, and increased instances of allergies and asthma later in life. Unicef has made skin-to-skin contact a key component of its birthing standards, citing the practice's power to "enable colonisation of the baby's skin with the mother's friendly bacteria, thus providing protection against infection."

When this protection is weakened by damage, or by the presence of harmful bacteria, the microbiome's delicate balance can be thrown off. This imbalance has been linked to dry skin, eczema, acne and psoriasis and, according to the Skin Microbiome in Healthy Ageing (SMiHA) network, some 50 per cent of the UK population suffer a microbiome-associated skin complaint each year.

"Chemicals in skincare products can disrupt the skin's delicate balance of oil and bacteria"

"The chemicals in skincare products can disrupt the natural microbiome of the skin's delicate balance of oil and bacteria," says Kinsella. "Antibacterial agents are a big factor in this, and other products with harsh chemicals that alter the skin's natural pH balance."

Once unbalanced, the microbiome can't as effectively protect against further bad bacteria, and a vicious cycle occurs. With eczema, bad bacteria causes the skin to become inflamed, patients scratch their skin therefore damaging it further, which lets more bad bacteria in.

Kate Porter, founder of skincare brand Harborist, explains further: "More severe eczema and dry skin has been associated with an abundance of a bacteria known as *Staphylococcus aureus*. There is evidence that reducing *S. aureus*, to restore a more diverse microbiome population, reduces symptoms of eczema. But it's a chicken and egg situation. Does the imbalanced microbiome cause these issues or vice versa?"

As we age, our microbiome then goes through further shifts. This shift is not only associated with visible changes – wrinkles, dark spots, dry skin – but with internal changes, too. There is one school of thought that as our microbiome changes with age, our skin's ability to protect us from UV radiation decreases, thus increasing our susceptibility to skin cancer.

Recent studies have shown the skin microbiome to be a more accurate predictor of chronological age compared to the gut. With this theory, a person's microbiome could, hypothetically at least, be used to assess life expectancy. "Ageing has a profound effect on the skin microflora in terms of both species and numbers," explains the team leading the SMiHA. "Human skin presents an excellent system to establish how changes in the microbiome influence biological age."

That's not to say microbiomes are the sole cause of such conditions and diseases – genetics and lifestyle play significant roles, for instance – but disruption to our skin's ecosystem is a contributing factor.

Yet just as everyday products have been linked with disrupting the microbiome, an increasing number of brands are now releasing products infused with prebiotics, probiotics and postbiotics to balance this

disruption. While probiotics refer to 'friendly' bacteria, and prebiotics are nutrients that feed these probiotics, postbiotics are what's left behind in the process. The jury is still out on the benefits of topical probiotic and prebiotic skincare, largely due to the infancy of the research and the fact the use of live bacteria in cosmetics is a regulator sticking point, but postbiotics in skin products are already commonplace. Lactic acid, for instance, found in off-the-shelf skincare, is a by-product of the fermentation of a probiotic called *Lactobacillus*. When applied topically, it has been shown to hydrate, reduce the signs of ageing and calm redness.

Researchers are also looking into the possibility of microbiota transplants to solve skin problems. In one study published in 2018 in the journal *JCI Insight*, an abundance of *S. aureus* in the microbiomes of people with atopic dermatitis was replaced with a bacteria known as *Roseomonas mucosa* "with significant decreases in measures of disease severity, and topical steroid requirement".

The issue with these findings, however, is that the underlying mechanisms of the skin microbiome remain largely unknown, and its impact is disputed. For all the studies linking C-section births with lower immunity, other studies fail to find the same correlations, or find associations that are statistically irrelevant.

"When the skin is healthy, we believe the skin microbiome is healthy too, however we don't know this for sure," says the SMiHA team. "Our understanding of how to manipulate the skin microbiome using everyday products is still very poor."

Recently, initiatives such as the Skin Trust Club have started collecting samples from the public to delve deeper into our skin health and its inner workings.

"There is a huge commercial pull to explore how to improve skin through a microbiome-targeted approach," concludes the SMiHA team. "However, separating the effects of topical products on the microbial population and the skin cells – in a way that allows us to be able to categorically say microbial targeting drives healthier skin – is a tough challenge for the scientific community."

—

by **VICTORIA WOOLLASTON** *(@vickywoollaston)*
Victoria is a technology and lifestyle journalist and editor.

COMMENT

W BOSON: IS ABOUT TO BREAK PHYSICS?

The mass of the W boson, a subatomic particle, appears to be wrong. What could this mean for the Standard Model of particle physics?

A new measurement from an old experiment may have just given us a huge clue to some big unanswered questions in physics.

The Collider Detector at Fermilab (CDF), a particle accelerator experiment which operated until 2011, recently caused a stir by re-measuring the mass of a particle known as the 'W boson'.

Each of the four fundamental forces (the strong force, the weak force, electromagnetism and gravity) has associated particles which 'carry' the force: for example, the photon – a particle of light – is a carrier of the electromagnetic force. The W boson is one of the carriers of the weak force.

It is unusual for an experiment which stopped taking data more than a decade ago to rouse such interest. The reasons are subtle, but compelling. To see why, let's step back and see where our knowledge of the fundamental forces and constituents of matter – expressed in the so-called 'Standard Model' – stands at present.

The Standard Model describes the strong, weak and electromagnetic forces, and all known elementary particles. The theory explains the mass of the W (and all the other fundamental particles), and also predicted the existence of the Higgs boson, which was discovered at CERN in 2012. This 'completes' the Standard Model, but leaves several questions unanswered. For example, how does gravity (a glaring omission from the model!) fit in? Why, according to astrophysical observations, is there a lot of so-called 'dark matter' in the Universe, and what is it? Why is there so much more matter than antimatter? The Standard Model is clearly not the full story, and many extensions to it have been postulated.

The Standard Model is a subtle framework, though. In the subatomic world of quantum mechanics, particles influence each other even when there is not enough energy around for them to exist. They can traverse tiny loops, forming and annihilating before they are directly observed. We call them 'virtual' particles, but their influence is very real and measurable. One thing they do is influence particle masses, with the consequence that while

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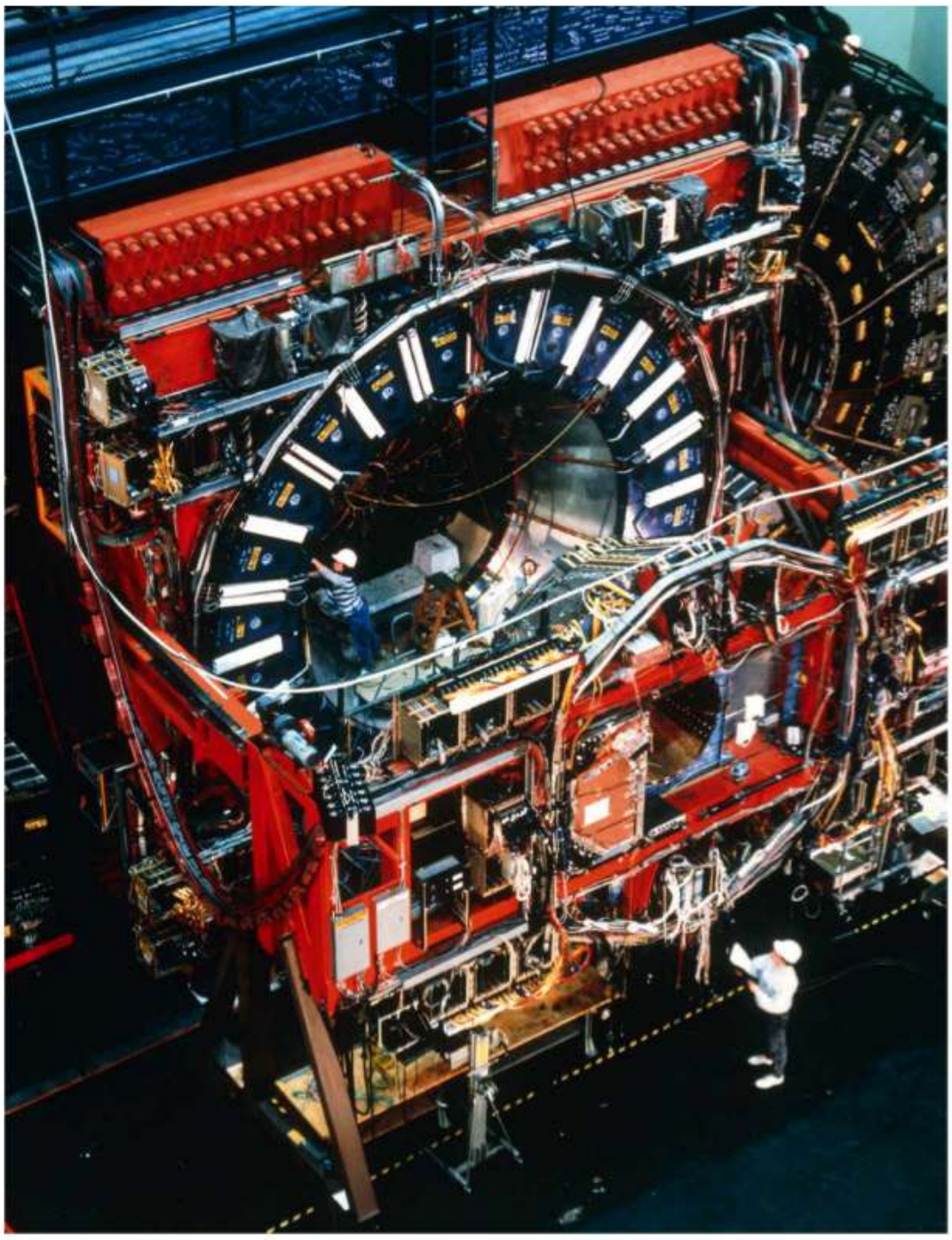
"The new mass measurement does not agree with the calculated W mass. If you made this CDF measurement a million million times, you'd only expect one discrepancy this big"



ABOVE The Collider Detector at Fermilab

the Standard Model does not predict the absolute values of particle masses, it does predict – very precisely – some relationships between them.

Back to the W mass then. It can be measured directly, which is what CDF has done (and more on that in a moment). But it can also be calculated using all the other measurements we have made, combined with the relationships between masses in the Standard Model. The directly measured value should agree with the calculated value, otherwise something is wrong. Excitingly, there could be new, beyond-the-Standard-Model virtual particles participating in those loops.

The interest has risen because the new CDF mass measurement does not agree with the calculated W mass. If you made this CDF measurement a million million times, you'd only expect one discrepancy this big, if the Standard Model is correct.

As always, there are some reasons for caution. CDF measured W bosons produced in high-energy collisions between protons and anti-protons. The measurement has taken over a decade because it is very hard to be so precise. When a W is produced, it decays instantaneously, and one of the things it produces is a neutrino, which CDF cannot detect. Information about the neutrino (and hence about the W mass) is calculated from assuming it must balance everything else produced in the collision. This means many different sources of uncertainty can have a significant influence, such as the distribution of particles inside the proton, extraneous background particles, and of course the precise geometry and accuracy of the detector itself.

Even so, mistakes can never be completely ruled out, and the new measurement is in fact somewhat out of line with other measurements, even those made earlier by CDF. Now the result is out there, it will receive a level of scrutiny few other measurements get, and other experiments, especially those at CERN, will be trying hard to match its precision and confirm or refute the discrepancy.

That said, this is a very strong hint that the answers to some of the big questions left open by the Standard Model may soon be within reach, just as the Large Hadron Collider starts its third running period and will itself be increasing the precision with which it can probe the energy frontier. **SF**

by **PROF JON BUTTERWORTH**
Jon is a physicist at University College London and works at the CERN Large Hadron Collider.

↗ A modular action cam built for adrenaline junkies p40

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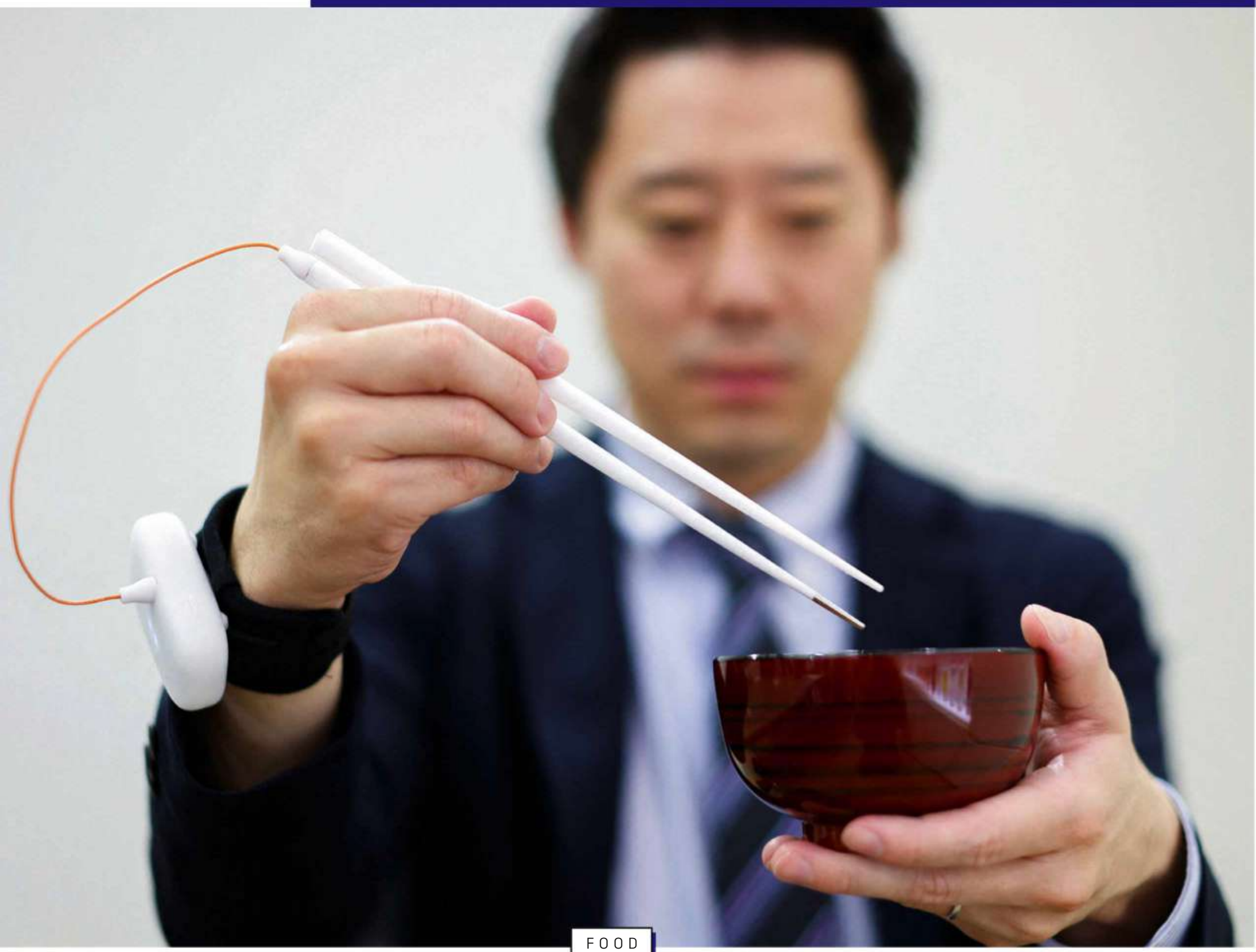


FOOD

Electric chopsticks that tickle your taste buds

Japanese researchers have found a way to lower salt intake without ruining food

MORE FOOD GADGETS

THE AI CHEF

A South Korean start-up, Beyond Honeycomb, has created its own AI fine-dining chef. A master chef prepares a meal, then the AI spends 48 hours learning all of the skills required to perfectly replicate it. The company hopes this will make fine dining more affordable.

THE WASTE REDUCER

Food waste is a major issue, and Orbisk is looking to solve it. A sensor above your food bin measures and recognises what kind of food is being thrown away, how much of it and at what time of the day. This data is then presented to you, allowing you to see how much food you actually need to buy.

THE AUTO TRACTOR

John Deere has created a tractor than can run completely autonomously. John Deere claims that a single tractor could prepare 325 acres of soil in just 24 hours, ready for planting. This would greatly boost farmers' productivity and reduce their workload.

These chopsticks use a gentle electric current to make food taste saltier, in an effort by Japanese researchers to reduce the sodium levels in a national diet that relies heavily on salty ingredients like soy sauce and miso.

They look like a pair of typical chopsticks, just with a set of wires sticking out that connect to a small wrist computer. The utensils work by passing a weak electric current through one of the sticks, which draws out sodium ions from the food (the chemical component that gives salt its savoury taste). The wrist computer modulates the current to create a unique waveform, which the researchers say is so gentle that it poses no danger to the diner.

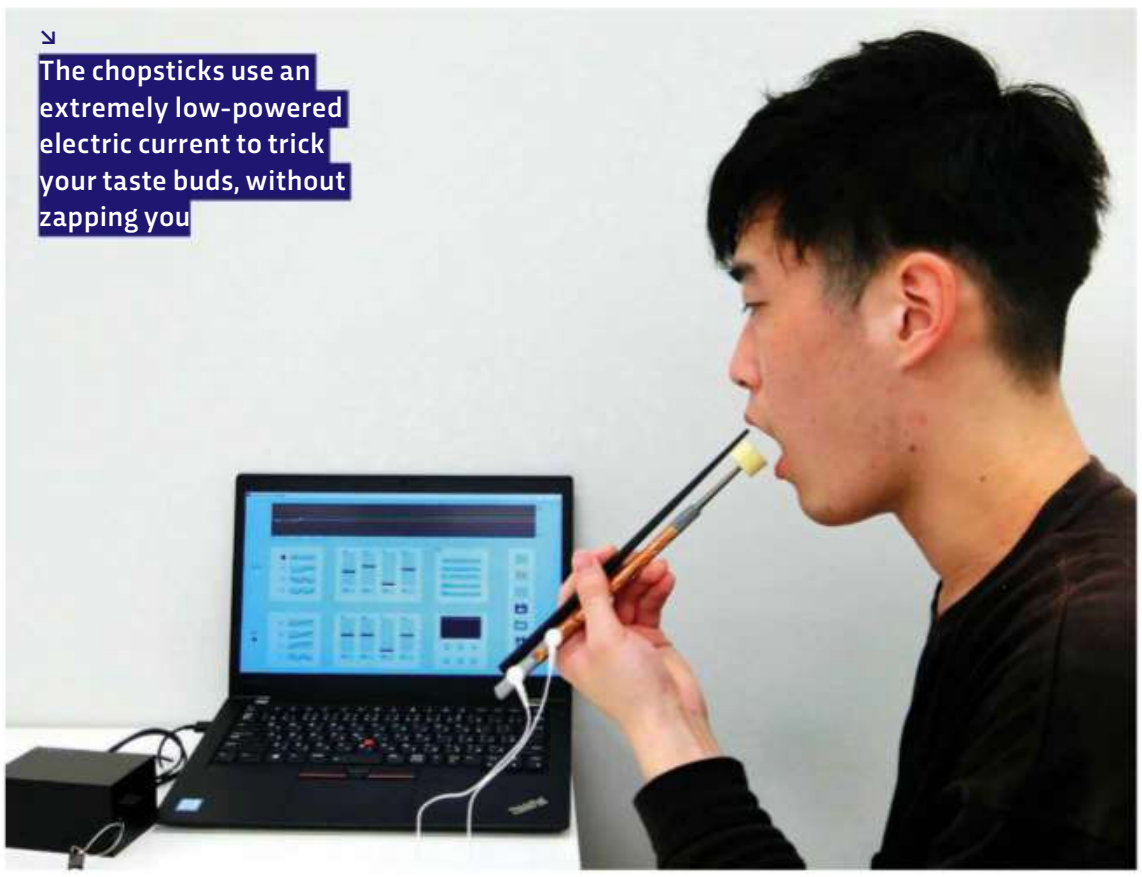
While this technology has potential across the world, it is especially useful in Japan. The researchers – a collaboration between a lab led by Homei Miyashita from Meiji University of Tokyo and food and drink manufacturer Kirin Holdings – highlighted that the daily salt intake of Japanese adults is 10.9g for men and 9.3g for women. That is much higher than the World Health Organization's recommended salt intake standards of less than 5g per day. "To prevent diseases, we need to reduce the amount of salt we take," says Kirin Holdings researcher Ai Sato. "If we try to avoid salt in a conventional way, we would need to endure the pain of cutting our favourite foods from our diet, or endure eating bland food."

In clinical tests, people who follow a low-sodium diet confirmed that the device enhanced salty tastes of low-sodium food by about 1.5 times. They also described reduced-salt soup as being rich and flavourful with the chopsticks, and found they could achieve similar levels of satisfaction with much lower amounts of salt in most meals tested.

This isn't the first time that Miyashita has put his mind to the world of taste. He is possibly best known for his creation of a lickable TV screen that is able to imitate various flavours.

"IF WE TRY TO AVOID SALT IN A CONVENTIONAL WAY, WE WOULD NEED TO ENDURE THE PAIN OF CUTTING OUR FAVOURITE FOODS FROM OUR DIET, OR ENDURE EATING BLAND FOOD"

The researchers are hoping to refine the product and plan on making it available to consumers in the next year. Kirin Holdings is also looking to design further products that can offer health benefits and taste combinations, mostly around the world of low-sodium dietary requirements.



The chopsticks use an extremely low-powered electric current to trick your taste buds, without zapping you

REUTERS, KIRIN HOLDINGS, BEYOND HONEYCOMB, ORBISK, JOHN DEERE

The iPhone SE

REVIEW

iPhone SE: Apple on a budget

At £419, it's half the price of Apple's flagship phone, but is it only half as good? **Daniel Bennett** tests it out

How clever does a smartphone really need to be? A look at my Screen Time app tells me that 85 per cent phone usage is spent either watching YouTube, listening to music, or scrolling through Twitter. Clearly, I've wasted my money on a top-of-the-range phone – a 20-something-core processor is a bit over the top for binge-watching *Binging With Babish*.

So, I skipped the new iPhone 13 to spend a month with the latest iteration of the iPhone SE instead – a handset that's less than half the price of the newest, smartest iPhone available – to find out whether it's time for a rethink when it comes to how much I spend on my phone.

WHAT ARE THE UPSIDES?

A quick read of the spec sheet tells you this isn't just old tech repackaged at a reduced price. Apple equips the iPhone SE with the same chipset, the A15 Bionic Chip, that it uses in its latest, most powerful phones. This means there's absolutely nothing wrong with how the phone performs. Apps load in an instant, the touchscreen never hangs and there hasn't been a website or a game that has caused the phone to stutter. Plus, it's technically powerful enough to handle editing photos and even 4K video.

It's a similar story for the camera, which punches way above its weight, thanks to the chipset inside. The A15 has what Apple calls a Neural Engine, which is there to help your iPhone understand the world around it. In terms of photography, this means that, in theory, your phone's camera can tell the difference between the blue in the sky, and the blue in something like a road sign, and then tune one or the other independently depending on which 'photographic style' you've chosen. There are four styles to choose from: Rich Contrast, Vibrant, Warm and Cool. You might, for example, want to capture a photo with a warmer looking sky, but that doesn't mean you want every single blue in the image to become more saturated – this is what the Neural Engine figures out. Similarly, Apple says the same tech improves the way your camera captures skin tones too. In practice, it's hard to fault.

The camera also pulls off Apple's newest software trick: point the lens at a document, poster or sign, and the camera will give you the option to copy the words off the live view and paste the text into a note, document or email. It'll even recognise when a line of text is actually a web link, and invite you to click it to head to the address.

APPLE X2

On top of a powerful CPU, you're also buying into Apple's OS, which is clean, simple and easy-to-use. It also comes with powerful privacy tools that can help keep nosy apps at arm's length. Plus, the phone offers wireless charging and waterproofing, which you don't often find in similarly priced Android devices.

WHAT'S MISSING?

If you're downgrading, the first thing you'll notice is the display. Compared to the edge-to-edge screens we've become used to, the black bars at the top and bottom that frame the display feel like a step back in time. On its own the screen is bright and crisp, but put it next to an OLED display you'd find on a flagship phone and the iPhone SE's LCD is notably less vibrant. Ultimately, it's the size of the screen (4.7") more than the picture itself that would potentially put me off the device long-term: it's just a touch too small for long stints on YouTube or a video game.

The storage on the base model, 64GB, is a little on the shallow side. The battery life also falls a little short of what you'd hope for, occasionally needing a recharge before the day was out.

As a point-and-shoot camera, we like the iPhone SE, though it's worth noting you'll be missing out on a few features. There's no zoom or wide-angle lens, and there's no dedicated night-mode, which means photos taken in low light can come out blurry and lacking definition.

VERDICT

For the tech-obsessed, the iPhone SE might not be tempting enough for a downgrade. The iPhone 13 Mini is probably a better option, if you're hoping to save some money and aren't willing to sacrifice that much screen space. For rest of us, this SE is a great option. In fact, I think there are two groups who Apple might have in mind with this phone: our parents and our kids.

The display, though small, is perfectly good for my mum or my nieces, who don't (yet) spend hours on their phones. The iPhone SE is easy to use, will look after their privacy and will be good enough to take and send all the picture they take, without breaking the bank. Most of the tech that's been omitted to make the phone affordable is superficial, while core components are powerful and, to a degree, future-proof. Ultimately, at half the price, it doesn't feel like you're getting half the phone.

↑ The iPhone SE's design with thumbprint sensor and black borders feels a touch outdated

Ideas we like...

↓

...an action camera with some versatility

Action cameras need to be versatile to capture every cliff jump, dirt bike trail or gnarly wave on film... and that's where the new Insta360 ONE RS comes in. As far as action cameras go, this is one of the more unique options. It uses a modular design, offering a detachable 360° lens, wide-angle lens and a 4K action camera that you can easily switch between. You can also detach the battery, allowing you to carry back-ups that you can snap in place quickly between stunts.

Insta360 ONE RS,
£499, insta360.com

↑

...shoes made using dandelions

The sustainable shoe market is blowing up right now, with companies competing to create the shoe that leaves the smallest carbon footprint. One of the more unique attempts is the Generation ZERØGRAND II. The upper is made out of a vegan microfibre that's 21 per cent recycled materials, and a felt fabric made mostly out of plastic bottles. The laces are completely recycled too, and the most unique part, the soles, contain a minimum of 25 per cent natural dandelion rubber!

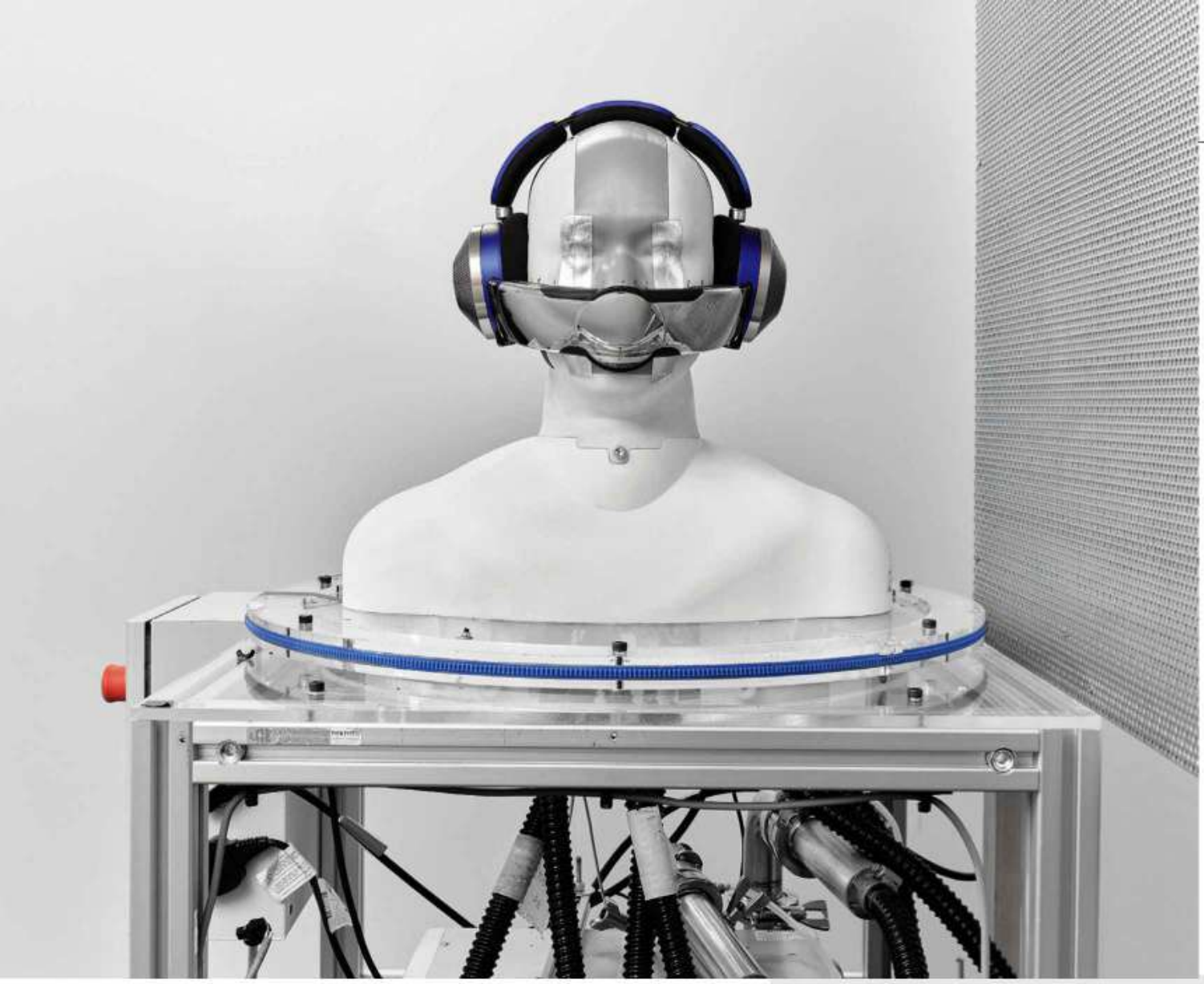
Generation ZERØGRAND II
£115, colehaan.com

↑

...a soundbar that adapts to its surroundings

The Devialet Dione wouldn't look out of place in Darth Vader's boudoir. It's even got its own little Death Star in the middle. Behind the Sith-lord aesthetic there are a total of 17 drivers – eight acting as subwoofers, eight as full-range audio and one central driver in a detachable orb that you aim towards the listeners for a direct experience. Hopefully it's a little better put together than the one Luke and friends blew up, twice.

Devialet Dione
£1,990, devialet.com



...air-purifying headphones

Stepping away from its usual market of vacuum cleaners and fans, Dyson's latest venture is a pair of headphones with a face mask – yes, you read that correctly. Though it looks like a cyberpunk muzzle, the mask is actually an air purifier designed to stop germs and pollutants from ruining your commute. The fact that no one will sit next you while you're wearing one is simply a bonus. The audio specifications are certainly impressive and they've been through Dyson's meticulous testing process, which has us intrigued. We'll just have to wait to find out if they really work, and to see if they fire your phlegm at fellow commuters.

Dyson Zone
£TBC, dyson.com

↑ ...a drone that can withstand an apocalypse

If Batman had a drone, this is what it would look like. The DJI Matrice 30 Series is not your average consumer drone. It is resistant to intense heat, high wind speeds, and heavy rain. There are three cameras on board and a laser rangefinder. It can zoom in up to 200x, use thermal imaging or shoot at night, and it can even map out terrain and report information back to multiple devices at once. Unfortunately, you'll also need Bruce Wayne's wallet to buy one.

DJI Matrice 30 Series
$9,999 (£7,800 approx), dji.com

↓ ...a TV and monitor all rolled into one

Squint your eyes and Samsung's new M8 monitor looks identical to Apple's recent colourful iMacs… probably a coincidence. However, with an affordable price tag, and an overkill of connection options, the Samsung M8 could be the perfect monitor for a lot of people. It doubles up as a telly, offering smart TV with Netflix, YouTube and most streaming platforms, as well as connection options for laptops, AirPlay for Apple products and even DEX to connect your Samsung smartphone as a computer. Not enough? It also has built-in speakers, a 4K display and an added webcam. You can even do a bit of web browsing on it, too.

Samsung Galaxy M8,
£699, samsung.com

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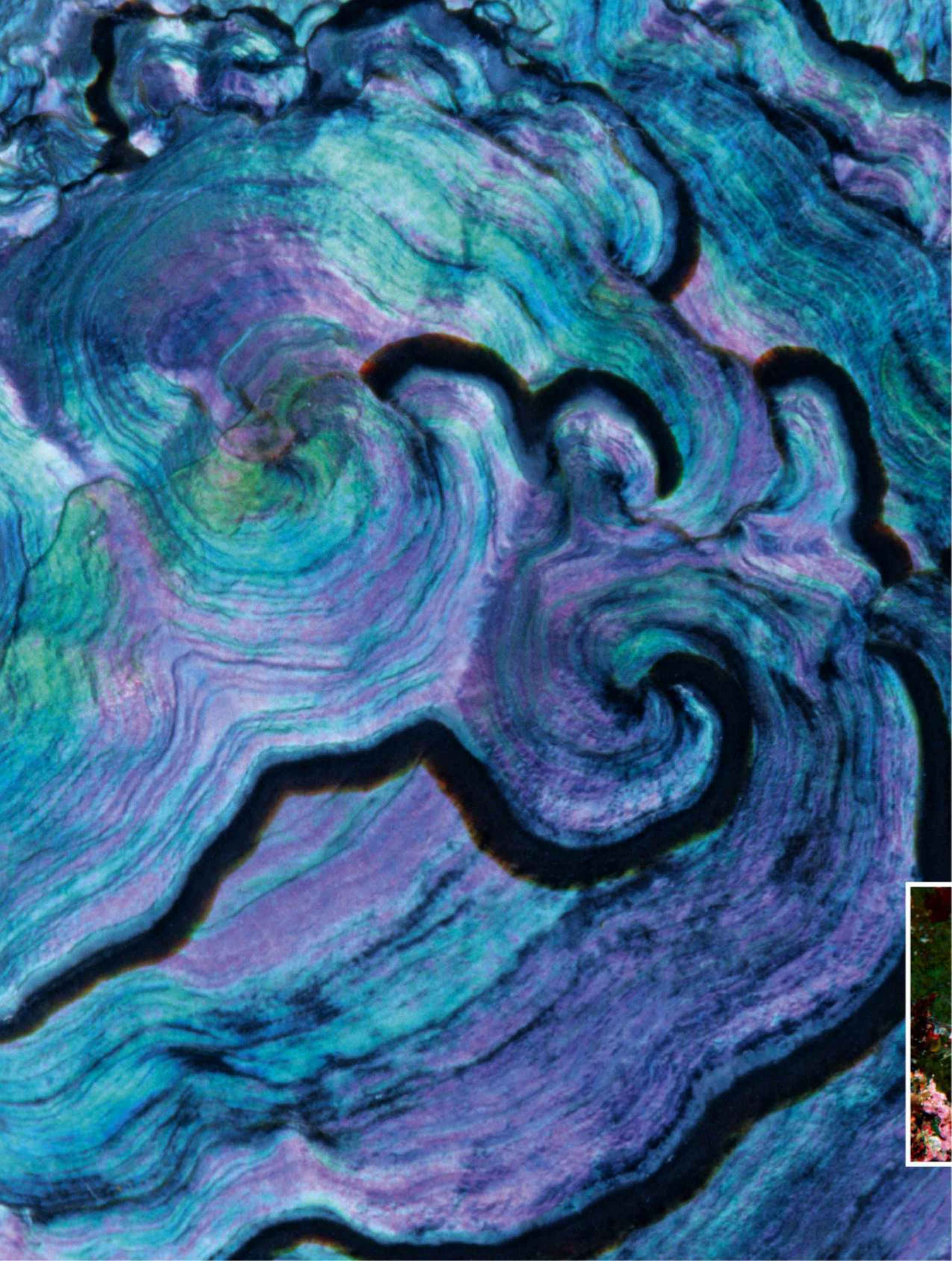
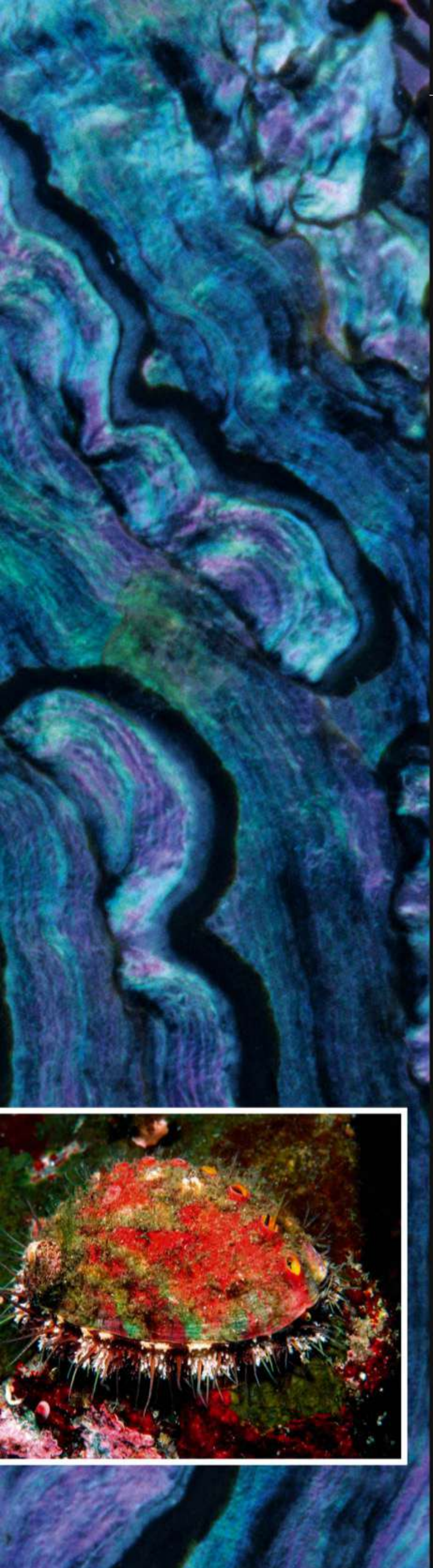
THE PRODUCTIVE BRAIN





CLAUDIO CONTRERAS/NATUREPL.COM, ALAMY

A WHOLE NEW WHORL

MANY OF US HAVE SEEN SEASHELLS ON THE BEACH AND MARVELLED AT THEIR COLOURS, AND PATTERNS OF CURVES AND RIDGES. BUT SEASHELLS ARE FAR MORE THAN JUST PRETTY OBJECTS, AND THEIR INTRICATE STRUCTURES CAN HELP US LEARN MORE ABOUT THE INHABITANTS THAT ONCE DWELLED INSIDE THEM

WORDS: DR HELEN SCALES

PURPLE STAIN

ABALONE

Abalone shells are gleaming and shiny on the inside, thanks to layers of nacre, the same stuff that pearls are made of. Nacre is 95 per cent calcium carbonate – chalk, essentially – but try dropping an abalone shell and you'll see it's virtually shatterproof. This super strength comes down to nacre's microscopic structure of diamond-shaped crystals stacked like bricks, with layers of chitin in between. Chitin is the same tough protein that makes insect exoskeletons and shrimp shells. If the outside of the shell gets damaged, the inner nacre layer stops cracks from growing bigger. The nacreous crystals slide over one another and the chitin stretches, dampening the energy of a spreading crack and halting it in its tracks.

Scientists from Canada's McGill University recently mimicked the structure of nacre using glass flakes and acrylic to produce a transparent composite that's three times stronger than normal glass and five times more resistant to fractures. Easy and cheap to make, this could be the ideal material for the next generation of smartphone screens that won't smash no matter how hard they're dropped, all inspired by nature's nacre.

↑

BUOYANCY AID

CHAMBERED NAUTILUS

This is the view inside the shell of a chambered nautilus that's been sliced into two halves, left and right. When the nautilus was alive, each of those chambers was filled with gas, which turned the shell into a buoyancy device. The floaty shell helps a nautilus to hover in the water column and therefore save energy.

Of all the cephalopods – the group of molluscs including octopuses and squid – it's only chambered nautiluses that live inside shells. All the others either abandoned their shells entirely or have modified internal shells, like the cuttlebones of cuttlefish that often wash up on beaches.

The elegant whorl inside the shell is what mathematicians call a 'logarithmic spiral'. Tracing the line from the midpoint outwards, the spiral expands by a constant amount for each 360° spin. It's made by the nautilus throughout its life as it grows bigger, adding more calcium carbonate to the shell's outer edge. Logarithmic spirals pop up throughout nature, from the seeds on a sunflower to the arms of a galaxy.

GETTY IMAGES X3

FEELING SPIKY

VENUS COMB MUREX

The Venus comb murex is one well-defended snail. With a shell that bristles with more than 100 sharp spines, it takes a brave and tough-jawed predator to attempt to eat one. The spines also help stop the shell from sinking into the soft seabed.

Murexes are voracious predators themselves. The shell's long channel houses a tube, called the siphon, which draws in water and lets the snail detect chemicals alerting it to the presence of prey. A living murex has a muscly foot sticking out of its shell. They creep up on other molluscs, grab them with their foot and then drill a hole in the shell with their sharp radula tongue. Then they insert in a feeding tube, or proboscis, and slurp out the soft innards.

Spines are a common defence among molluscs. Not only do they make shells difficult to handle and swallow, but they also help camouflage them by encouraging sponges and seaweed to grow on the outside.

INGO ARNDT /NATUREPL.COM, NORBERT WU/NTAUREPL.COM

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MASTER OF DISGUISE

CARRIER SHELL

Xenophora do pretty much what their name describes. Based on ancient Greek words, these are sea snails that 'carry strangers or guests'. In English, they're generally known as carrier shells. In this picture, you can just make out the original shell of this snail: it's the largest, twisting, all-white shell, which lies underneath a collection of found objects, including spiralling turret shells and cerith shells, clam shells and pebbles. Carrier shells have also been known to decorate themselves in chunks of corals and sponges many times bigger than their own shell. Some even pick up bits of human trash they find on the seabed, such as bottle tops.

To create their elaborate outfits, a carrier grabs an empty shell with its muscly foot and holds it in place. Then it uses its soft body tissue, called the mantle, to glue it in place. The bio-glue is made of calcium carbonate, the same material as the shells themselves. Using old shells is a cost-effective way for the carriers to make themselves bigger and harder for predators to identify and handle.

↑

DRESSED TO KILL

DALL'S CONE SNAIL

This is Dall's cone snail, one of around 700 *Conus* species famous for their beautiful shells and potent venom. Some cone snails hunt fish with a 'taser-and-tether' tactic. They harpoon victims by spitting out venomous teeth that cause instant paralysis – lethal, but with great potential in the human world. Cone snail toxins have inspired a drug that blocks pain signals in people suffering from chronic pain.

Other cone snails make toxins that mimic the hormone insulin and cause their victim's blood sugar level to crash, so they pass out. A research team recently took inspiration from cone snails to create a modified form of human insulin, which is fast-acting to give patients with diabetes more immediate control over their blood sugar.

Bea Ramiro from the University of Copenhagen studies a deep-sea cone snail whose hunting strategy is 'ambush-and-assess.' This snail's venom takes up to three hours to work, so after attacking its victim, it retreats and waits for it to die, much like rattlesnakes do. These slow-acting venoms mimic another common hormone, somatostatin, and could lead to new painkillers that one day might replace morphine.

↓

SNEAKY SHELL

ALLIED COWRY

This allied or false cowry is nestled in a soft coral on Sha Tong Hau Shan Island, south of Hong Kong. You can just make out its pink shell, but most obvious is the spectacular crimson and white mantle. This soft tissue sticks out of the shell's opening and most of the time completely covers it. The colours and white pimples closely mimic the polyps of the soft coral, giving the snail brilliant camouflage. Allied cowries are all parasites that feed on the octocorals they live on, including sea fans, sea whips and sea pens. Many allied cowries obtain pigments from their food and secrete them in their mantle, a process known as 'alimentary homochromy'. This helps make them an even closer colour-match as they hide among their hosts. Some cowries have brightly coloured mantles as a warning of the toxic chemicals they contain.

Like their close relatives, the true cowries, these sea snails use their mantle flaps to keep their shells shiny like porcelain. The mantle secretes layers of smooth calcium carbonate on the outside of the shell, stopping anything from growing on them.

MAGNUS LUNDGREN/WILD WONDERS OF CHINA/NATUREPL.COM, SCIENCE PHOTO LIBRARY

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COCKLES OF YOUR HEART

HEART COCKLE

Most bivalves – the molluscs with shells in two parts, like scallops and mussels – are filter feeders. They suck water into their shells through a siphon tube and pass it over their gills. These act as filters, collecting food particles. But heart cockles do things differently. They feed on sugars made by masses of single-celled algae, called zooxanthellae, that live inside their bodies. To make sure their zooxanthellae can photosynthesise, heart cockle shells are dotted with transparent windows that let the sunshine in. Essentially, their shells act as greenhouses. The partnership is a mutual one. The cockles get food, and the zooxanthellae get somewhere safe to live with plenty of sunlight.

Giant clams are close relatives of heart cockles and they have zooxanthellae in their mantles too. Giant clams also have specialised cells called iridocytes that contain tiny reflectors that scatter and reflect light. Recent studies at the King Abdullah University of Science and Technology in Saudi Arabia revealed that a giant clam's iridocytes absorb harmful UV light and then re-emit it as a longer wavelength which the zooxanthellae can use for photosynthesis. **SF**

by **DR HELEN SCALES**
Helen is a marine biologist, writer and broadcaster. Her latest book is What A Shell Can Tell *(£16.95, Phaidon Press).*

Time to change gear?

Whether you have a passion for visual storytelling or you're a casual hobbyist, transform the way you buy, sell and trade camera kit

The technology used in the film and photography industry is rapidly evolving and the same can be said for the kit required. Pro brands such as Nikon, Panasonic and Canon are making huge strides forward in producing impressive cameras, lenses and accessories. With newer, more cutting-edge gear constantly being introduced, there's always a shiny new camera on the market attracting interest and it can certainly be hard for keen camera enthusiasts to rise above it.

A common predicament is feeling the compulsion to always purchase new kit, and this is understandable. But you don't necessarily need a professional's budget to be a professional photographer. By and large, the type of camera you require will depend on the kind of photographer or videographer you are. However, the specification of a camera becomes especially important if you happen to specialise in an area of photography or film that demands particular features.

Of course, it goes without saying that you'll want to add value to your photography, whether it's a fun pastime or a part of your profession. But buying brand-new equipment isn't always feasible. Not to mention the fact that the added costs of accompanying kit such as lenses and batteries can really mount up, getting what you need can end up being a costly endeavour.

This is where MPB comes in. MPB is changing the way consumers buy and sell used photographic equipment with an online platform that makes it easier to access exceptional camera equipment.

Why choose used?

MPB has made it its mission to transform the way that people buy, sell and trade photo and video kit. Whether you're looking to upgrade your current camera, or just fancy trading in some unused kit, the process doesn't have to be risky. This is why MPB is trusted by 250,000 creatives around the world who sell more than 20,000 cameras and lenses every month.

You can use a simple online valuation tool that entails entering the details and the condition of the item you're selling. MPB's in-house experts will then get an instant valuation sent to you. It's that simple. You'll receive an offer for every piece of kit based on make, model and condition across a wide range of camera bodies, lenses, filters and accessories. If you decide to accept your offer, a courier will be arranged to pick up the kit from your doorstep at no extra cost. Finally, they'll check the items, confirm the quote and send the money straight to your bank account. MPB also offers a 6-month warranty, so you needn't worry about any costly repairs along the line.

Changing the bigger picture

You may not realise it, but trading or selling a used camera is a simple way to do your bit for the planet while making your money go further as well. Many people are already aware of the favourable pricing that comes with buying and selling used camera equipment; for example, a used setup costs up to a third less than buying one brand new. But environmental factors also play a big part in many people's decision to opt for used photography equipment.

MPB recirculates more than 300,000 pieces of used equipment every year, equipping visual storytellers worldwide with the gear they need. This gives a new lease of life to unused kit and keeps unnecessary waste out of landfills, helping not only to create a more sustainable future but also changing the way we think about common photographic practices.

If you want to save without compromising on quality, discover more about how you can upgrade or trade your camera from all the biggest brands with MPB at: mpb.com/en-uk/

FIND OUT MORE AT **MPB.COM**

LAB
GROWN
MEAT
GRILL-FREE
STEAK
GRILL-FREE
STEAK

EVERYTHING YOU NEED TO KNOW ABOUT A FUTURE WHERE YOU CAN HAVE YOUR STEAK AND EAT IT...

WORDS: AMY FLEMING

It wasn't long ago that the idea of the meat on our plates coming from vast stainless steel bioreactors, rather than farmed animals, seemed like science fiction. The notion has gone through numerous rebrands since its early positing as 'vat meat', which triggered unappealing visions of high-tech Spam. 'Lab meat' came next, as scientists perfected the recipe in small beakers in laboratories. Then came the more appetising-sounding 'cultured meat', as investment from high-profile individuals rocketed and producers positioned these products as having been brewed, just like beer. Now, 'cultured meat' has evolved to 'cultivated meat', which is the preferred term used by CEOs in the industry.

Whatever you choose to call it, with the future of global food security in question, and farmed meat a key culprit in climate breakdown, slaughter-free meat is starting to look increasingly like the future of food.

ILLUSTRATION: MAGIC TORCH

HOW IS THE MEAT MADE?

Rather than being part of a living, breathing, eating and drinking animal, cultivated meat is grown in anything from a test tube to a stainless steel bioreactor. The process is borrowed from research into regenerative medicine, and in fact Prof Mark Post of Maastricht University, who cultured the world's first burger in 2013, was previously working on repairing human heart tissue. Cells are acquired from an animal by harmless biopsy, then placed in a warm, sterile vessel with a solution called a growth medium, containing nutrients including salts, proteins and carbohydrates. Every 24 hours or so, the cells will have doubled.

Meat grown in the lab at the University of Maastricht in 2011. Two years later, the world's first cultured burger was created by the scientists

CEO of GOOD Meat Josh Tetrick

HOW DIFFERENT IS CULTIVATED MEAT FROM THE REAL THING?

Cellular farming doesn't grow cuts of meat, with bone and skin, or fat marbled through it like a succulent ribeye steak. Muscle cells require different conditions and nutrients to fat cells, so they must be made separately. When the pure meat or fat is harvested, it is a formless paste of cells. This is why the first cultivated meat products served up have been chicken nuggets or burgers.

The flavours, however, are of real meat. As they are produced in a sterile environment, there is less risk of contamination from disease and chemicals. This is in contrast to conventional agriculture where, says San-Francisco based Josh Tetrick, CEO of GOOD Meat, "you have a live animal slaughtered on the floor. If you look at the *Salmonella*, *E. coli*, faecal contamination that's part of animal agriculture, it looks much better from a cultivated meat perspective than it does from a conventional meat perspective."

IS IT AS NUTRITIOUS AS REGULAR MEAT?

A spokesperson for UPSIDE Foods, a San Francisco-based leader in the cultivated meat arena, says that the nutrient profile will be similar, but it will also be possible to enhance or even personalise it. "We are exploring ways to improve the nutrient profiles of our products. Whether that's less saturated fat and cholesterol, or more vitamins or healthy fats," they said. "For instance, imagine if we could produce a steak with the fatty acid profile of salmon? Or what if consumers could customise the nutrient profile in their products to meet their dietary needs?"

As there are so few cultivated meat products on the market requiring food labelling, we'll have to wait to get a better understanding of the nutritional value.

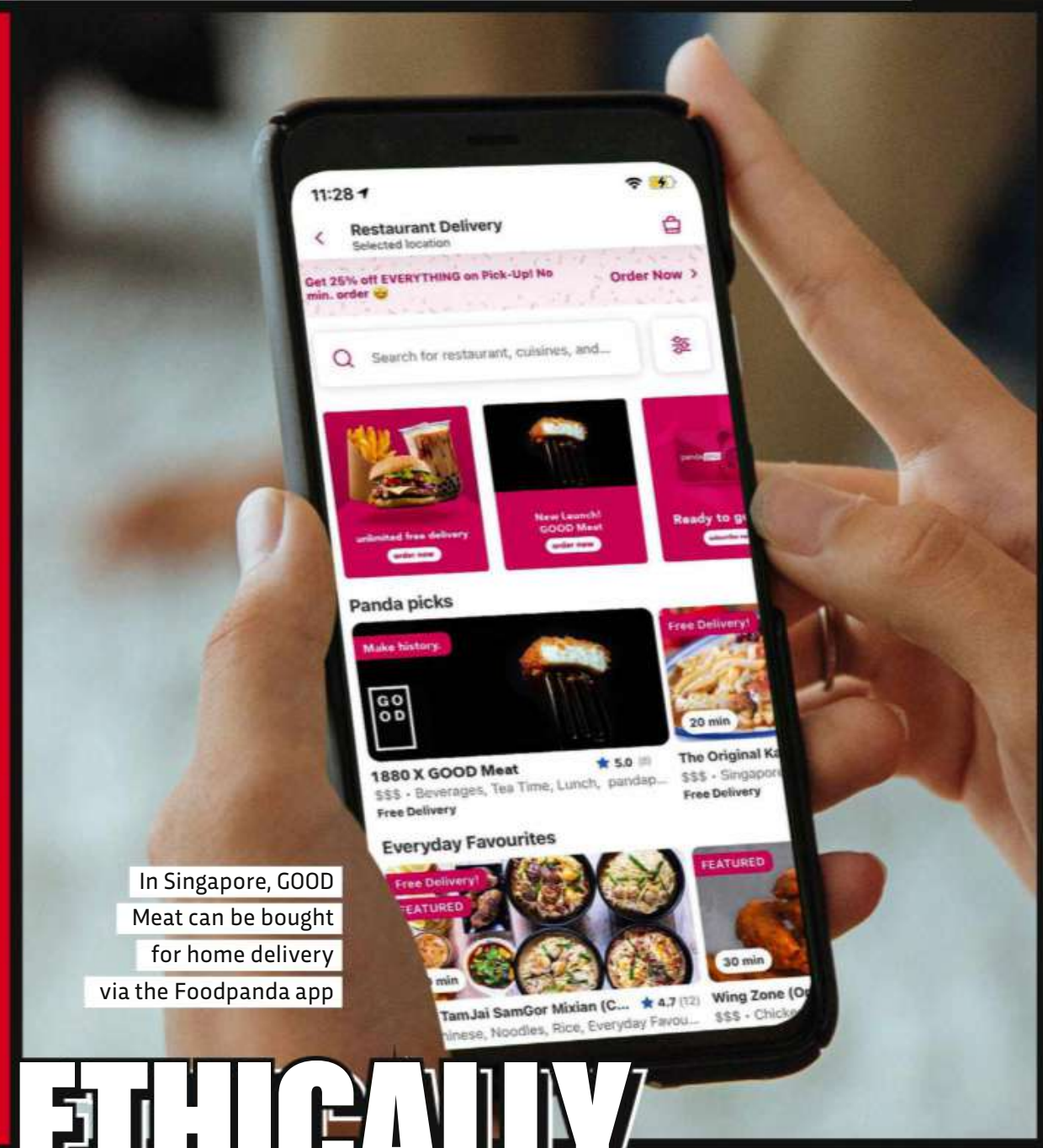
Cultivated chicken and beef from UPSIDE Foods

REUTERS, GETTY IMAGES, UPSIDE FOODS X2

WHEN CAN PEOPLE BUY IT?

People in Singapore already can. Tetrick's company, GOOD Meat, has been producing and selling its chicken in Singapore since December 2020 at special events, both in an upscale hotel restaurant and the legendary Mr Loo's hawker stall. Breaded chicken and shredded chicken have both gone down well. Tetrick says the company has applied to the US Food and Drug Administration (FDA) for approval in the US, but no timescale has been given. Other producers say that Western countries are still ironing out the details of how regulatory approval will work, but say they'll be ready to scale up as soon as approval is given in the coming years.

Muslims can only eat meat that has been slaughtered in a particular way. There is some disagreement on whether cultivated meat is halal



In Singapore, GOOD Meat can be bought for home delivery via the Foodpanda app

ETHICALLY, CAN EVERYONE EAT IT?

Now that the foetal bovine serum is out of the way (see p60), vegetarians could, ethically speaking, eat this meat – if they have an appetite for it.

The religious element is a little trickier. For meat to be permissible under Islamic and Jewish laws, there are strict rules on how animals are slaughtered and how the meat is prepared. Cultivated meat is set to trigger lively debates among religious leaders around the world (interpretations of scriptures vary geographically), and has already started doing so in some zones. Would cultivating meat from kosher or halal meat cells solve the problem? In Indonesia, which has the world's largest Muslim population, the influential Muslim organisation Nahdlatul Ulama has reportedly given a statement putting cultivated meat in "the category of carcass which is legally unclean and forbidden to be consumed."

In contrast, the Muslim-majority country Qatar is heavily investing in the technology, and building a production plant with GOOD Meat.

Meanwhile, in the London Beth Din (Court of the Chief Rabbi), there's excitement at the prospect of a meat that could be a neutral food, under kosher law. Foods in milk or meat categories must be kept separate, so to have a neutral meat could provide a convenient loophole. And it could eventually provide cheaper kosher meat, which traditionally tends to be expensive. As Rabbi Conway says: "This is an extraordinary breakthrough and potentially a very exciting development for the kosher consumer. If the meat was available on a commercial scale, we would need full details of the manufacturing process and the ingredients used to rule whether it was kosher, but potentially this could make life easier and cheaper for kosher consumers."

IS IT BETTER FOR THE ENVIRONMENT?

The truth is, we can't know until mass production is happening. Modelling the potential impacts of a fast-moving biotech industry that's still in development is subject to many ifs and buts. One 2019 study from the University of Oxford warned that the energy used to make cultivated meat could release more greenhouse gases than traditional farming.

Pelle Sinke, researcher at Netherlands-based sustainability consultancy CE Delft, who was not involved in the research, says the part of the study that assumed use of electricity generated by a large proportion of fossil fuels highlighted the importance of renewable energy for cultivated meat production.

"In some scenarios, cultivated meat had a higher global warming effect, and in some scenarios a lower effect, depending on consumption levels, expected energy use for cultivated meat and the beef cattle system it was compared to," he says. Sinke adds that the study doesn't, however, take into account the lower land use of cultivated meat. "[There's] the possibility to use that land for plant-based protein production, nature and extra renewable energy production, which in turn influences the CO_2 emissions of cultivated meat," he says.

His own team has also been investigating the environmental impact and he says that while cultivated meat is no silver bullet to solve all the world's problems, "it certainly has a lot of potential because it directly offers a more sustainable alternative to conventional meats. It is a more efficient way of converting crops into meat, and therefore much less land is needed to produce these crops. But it does use more energy. For a lower carbon footprint than conventional meats, it is crucial that renewable energy sources are used in its production, including in the supply chain – importantly for the production of nutrients and other ingredients needed for the culture medium."

All of the companies contacted for this article – Mosa Meat, GOOD Meat and UPSIDE Foods – understand that building sustainable energy into production is essential.

Depending on the scenario, cultivated meat can have either a higher or lower impact on the environment than regular farming

GOOD MEAT, ALAMY X2

WHAT CHALLENGES NEED TO BE OVERCOME?

Cultivated meat bioreactors, like these ones at UPSIDE Foods, will need to be far bigger if mass production is going to be possible

A vegan growth medium

Until recently, in order to kick-start cell division, about 20 per cent of the growth medium had to be foetal bovine serum, drawn from the blood of a cow foetus. Not only is the serum prohibitively expensive, but it's also distinctly not vegetarian. But all the major players now claim to have developed an alternative. This year, Post and his team published an academic paper about their foetal bovine serum alternative. The process uses genetically modifying yeast to produce the necessary proteins. This technology, called precision fermentation, is similar to how medical insulin is made (we have a lot more than beer and bread to thank yeast for!). Post says that there is a whole new burgeoning industry for producing vast vats of productive microorganisms.

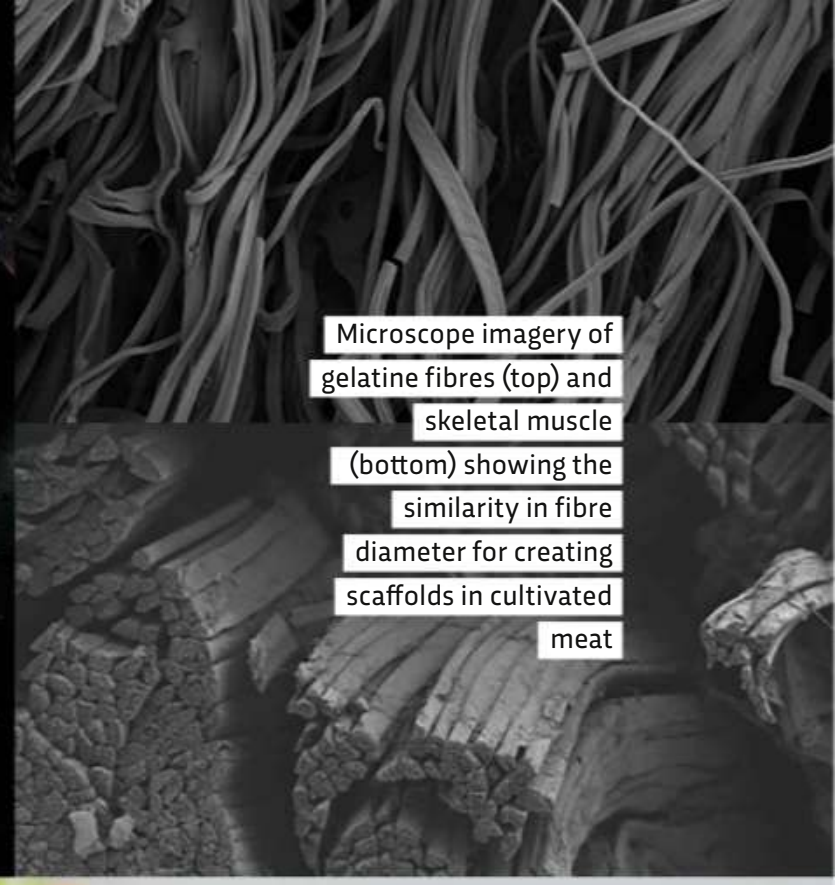
Tetrick admits, however, that there are still challenges with scaling up the alternatives, and that his chicken in Singapore is produced with foetal bovine serum. "[It's] not because we want to, but because it was included when we initially submitted our application, because we hadn't solved it when we submitted," he says. "We're awaiting regulatory approval to produce without it."

Mass production

Tetrick says that scale is the next great hurdle to clear. You need to be churning out "a minimum of 15 million pounds [6.8 million kilos] per year at a facility, which is sort of a rule of thumb for national distribution across the US or Western Europe." This will necessitate bioreactors that hold at least 200,000 litres, which has never been done in cell culture. "People eat it every week in Singapore… right now the largest size that we're [producing in] is 1,200 litres, which is very small, relative to what is required. In my mind, this is the single biggest limiting step of the entire industry."

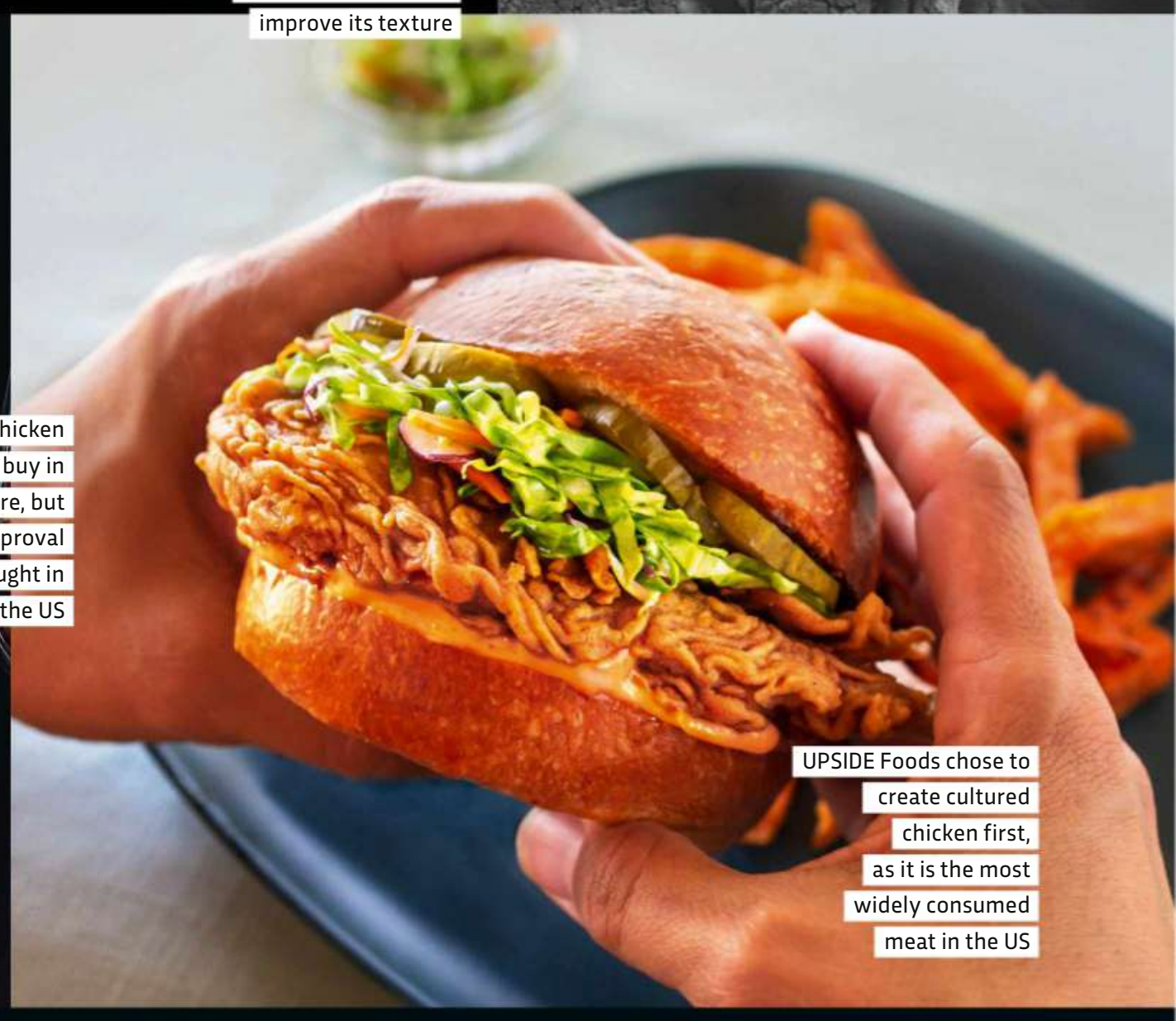
Only when produced at scale can the price come down and compete with cheap, intensively farmed meat. Meanwhile, GOOD Meat's Singapore operation is currently running at a loss, selling hawker stall dishes for four Singapore dollars (around £2.50). When

Gelatine fibres being produced to be added to cultivated meat to improve its texture



Microscope imagery of gelatine fibres (top) and skeletal muscle (bottom) showing the similarity in fibre diameter for creating scaffolds in cultivated meat

GOOD Meat's chicken is available to buy in Singapore, but regulatory approval is still being sought in the US



UPSIDE Foods chose to create cultured chicken first, as it is the most widely consumed meat in the US

UPSIDE FOODS X2, GOOD MEAT, HARVARD UNIVERSITY X2

launched in the West, all the products will start off at expensive restaurants – adding cachet to their launches – and can only trickle down to affordable supermarket prices with economies of scale.

Texture

Yes, much of the world's meat consumption consists of burgers, nuggets and sausages. But what if we want a juicy, cultivated steak? How do we turn meaty mush into a choice cut? It's a fast-moving picture, but GOOD Meat's current solution for their chicken products is to pair it with more structured vegetable proteins. Its offering in Singapore is 73 per cent chicken. "[And then the rest] is binders and fillers," says Tetrick. "We're trying to optimise it for the sensory and consumer experience: taste, texture, flavour profile, cost."

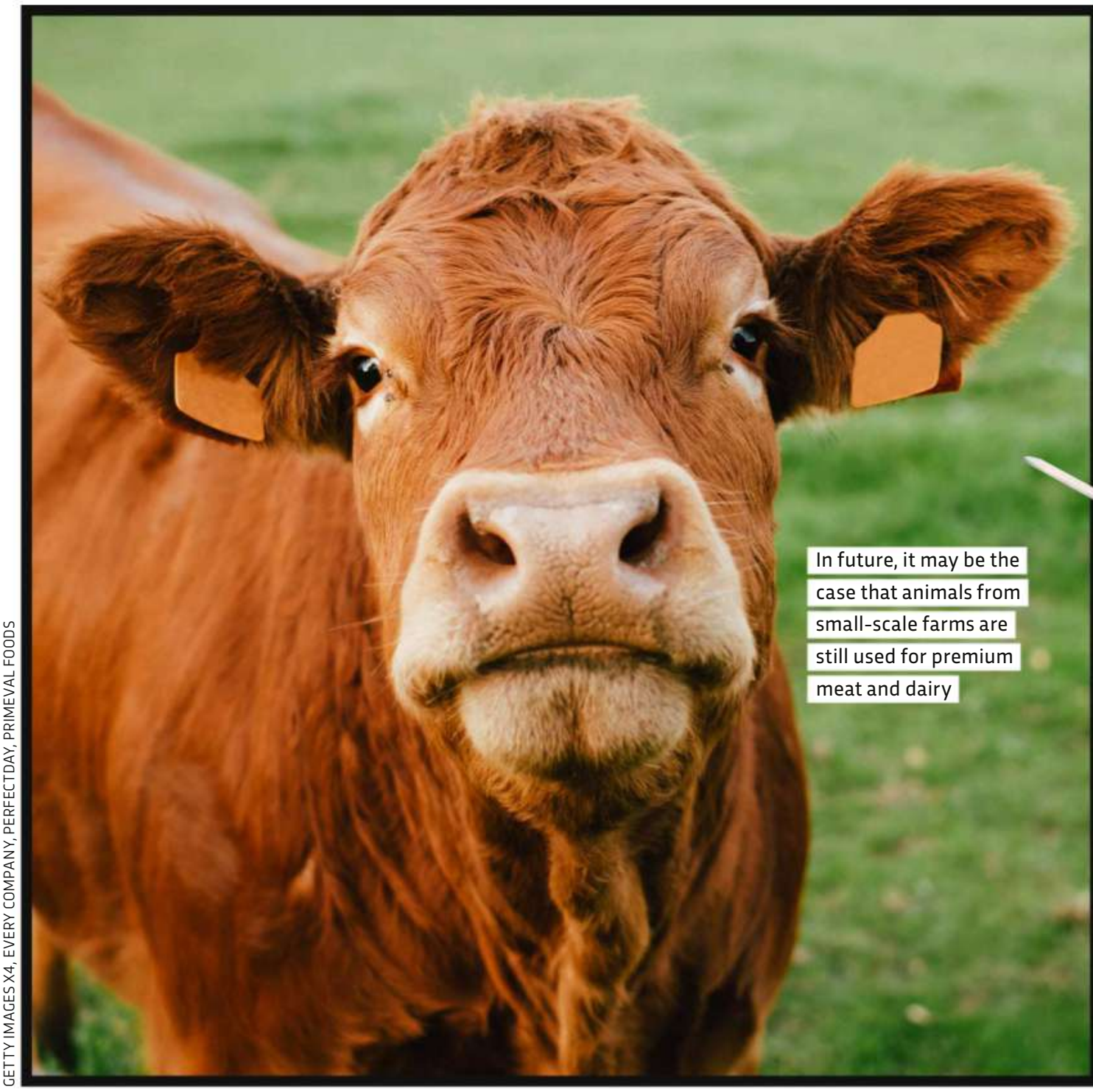
Cellular agriculture trailblazers argue that it's cheap burgers and chicken that are using up the majority of the one-third of the planet that's currently dedicated to growing farm-animal feed, so these products are both the most urgent and easiest to get to market. To achieve the texture of steak, says Tetrick, scaffold technology will be necessary, as a way of building structure inside the vessel. This scaffold will most likely be made using vegan collagen.

WHAT WOULD HAPPEN TO FARMERS AND THEIR ANIMALS IF CULTIVATED MEAT TAKES OFF?

"We envision that small-scale conventional farming will still be used for premium meat cuts and dairy products for years to come," says Post. "This protein transition will happen over decades, and innovations rarely completely replace existing practices. Cellular agriculture has the potential to create a more balanced and symbiotic relationship between small-scale farmers, consumers and the planet."

Post's team is already partnering with a farmer in the Netherlands, who keeps a free-roaming, high-quality herd of Limousins, raised not for slaughter, but for regular biopsies for Mosa Meat's burgers. "The same way that crop farming currently provides feed for animals, we also require feed for our cells, using the same type of nutrients a cow needs," says Post. "We will work with farmers to grow the crops needed to feed our beef cells."

UPSIDE Foods takes a similar view, while Tetrick says GOOD Meat is developing a beef line, culturing meat cells from a company called Toriyama, which is a high-end wagyu beef producer in Japan. "That's another interesting thing about cultivating meat – you can use these high-end meat sources and the cost to do it isn't any more," Tetrick says.



In future, it may be the case that animals from small-scale farms are still used for premium meat and dairy

GETTY IMAGES X4, EVERY COMPANY, PERFECTDAY, PRIMEVAL FOODS

IT'S NOT JUST MEAT THAT CAN BE CULTIVATED...

NO-HUNT EXOTIC BEASTS

Start-up Primeval Foods sees the next logical step in culturing meat cells as a chance to taste exotic, off-limits animals such as lion and zebra. After launching in 2022, Primeval Foods is already promising imminent tastings in London and New York, and has so far released pack shots of tiger steak and zebra sushi rolls.

DAIRY, WITHOUT THE COW

From milk to ice-cream to cream cheese, Perfect Day's milk protein is already available in over 5,000 stores across the US. But instead of being made by cattle, it's produced by a fungus genetically programmed to create cow whey protein, using the same precision fermentation technology responsible for medical insulin. And the best bit: it's lactose free.

EGG WHITES, WITHOUT THE CHICKEN

Precision fermentation is used by Every Company to make egg white, as well as a soluble version of the protein that even the fussiest palate would be hard-pressed to taste or see, making it an ideal additive for protein-boosting drinks and other products. SF

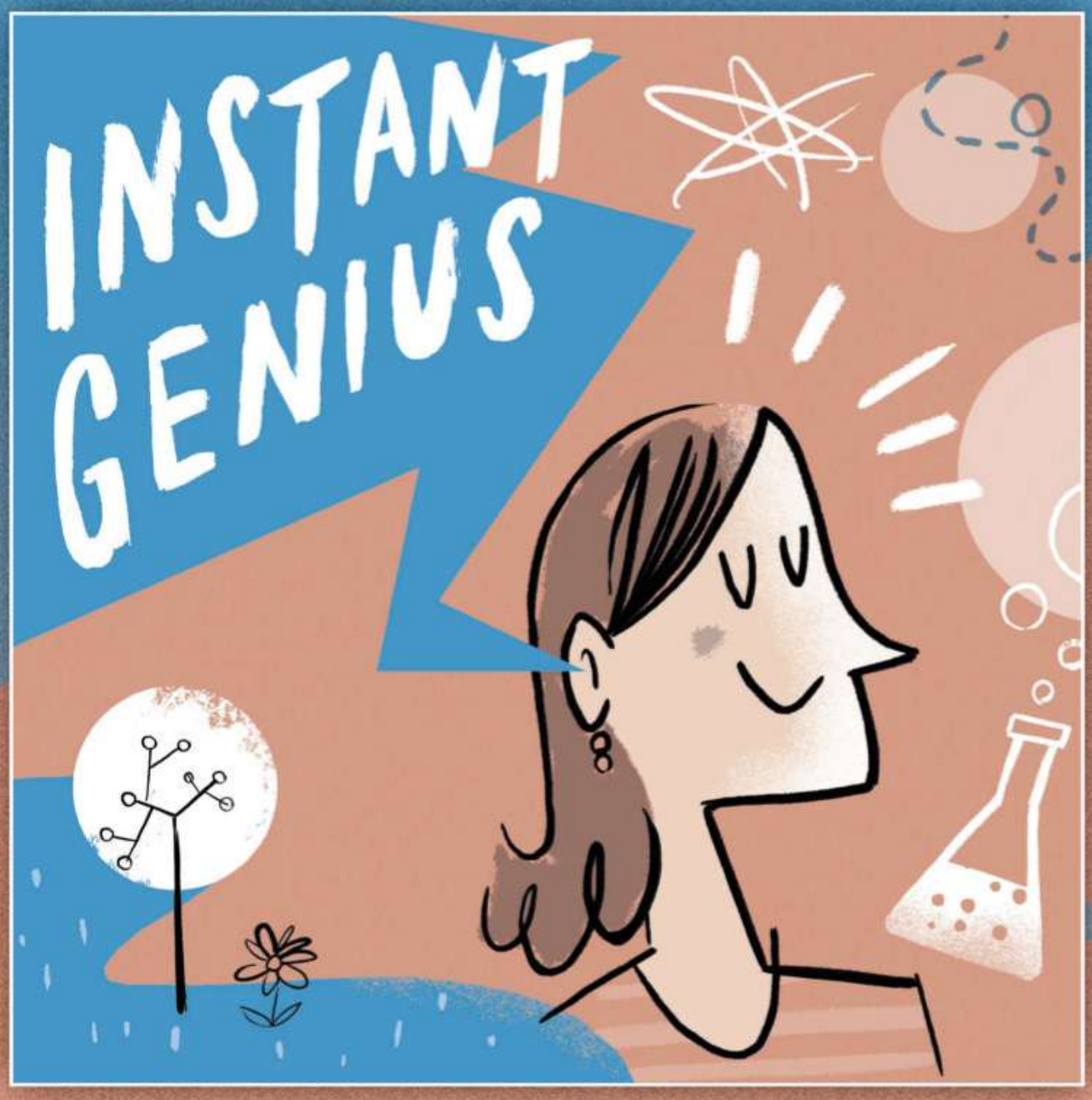
BLUEFIN TUNA, BUT NO FISHING

As the name suggests, Finless Foods is creating animal-free fish. The company cultures bluefin tuna cells in what it calls a microbrewery-style production facility. I was lucky enough to attend an early prototype testing in 2017, and I can confirm that the fish croquettes tasted subtly of a sea in which the cells had never swum.

by AMY FLEMING
(@amy_fleming)
Amy is a freelance science writer.

DON'T JUST READ THIS MAGAZINE... LISTEN TO US TOO

The all-new weekly podcast from the team behind *BBC Science Focus*



FEATURING

BRAIN MYTHS
with ***Dr Lisa Feldman-Barrett***

ALGAE
with ***Ruth Kassinger***

THE METAVERSE
with ***Prof David Reid***

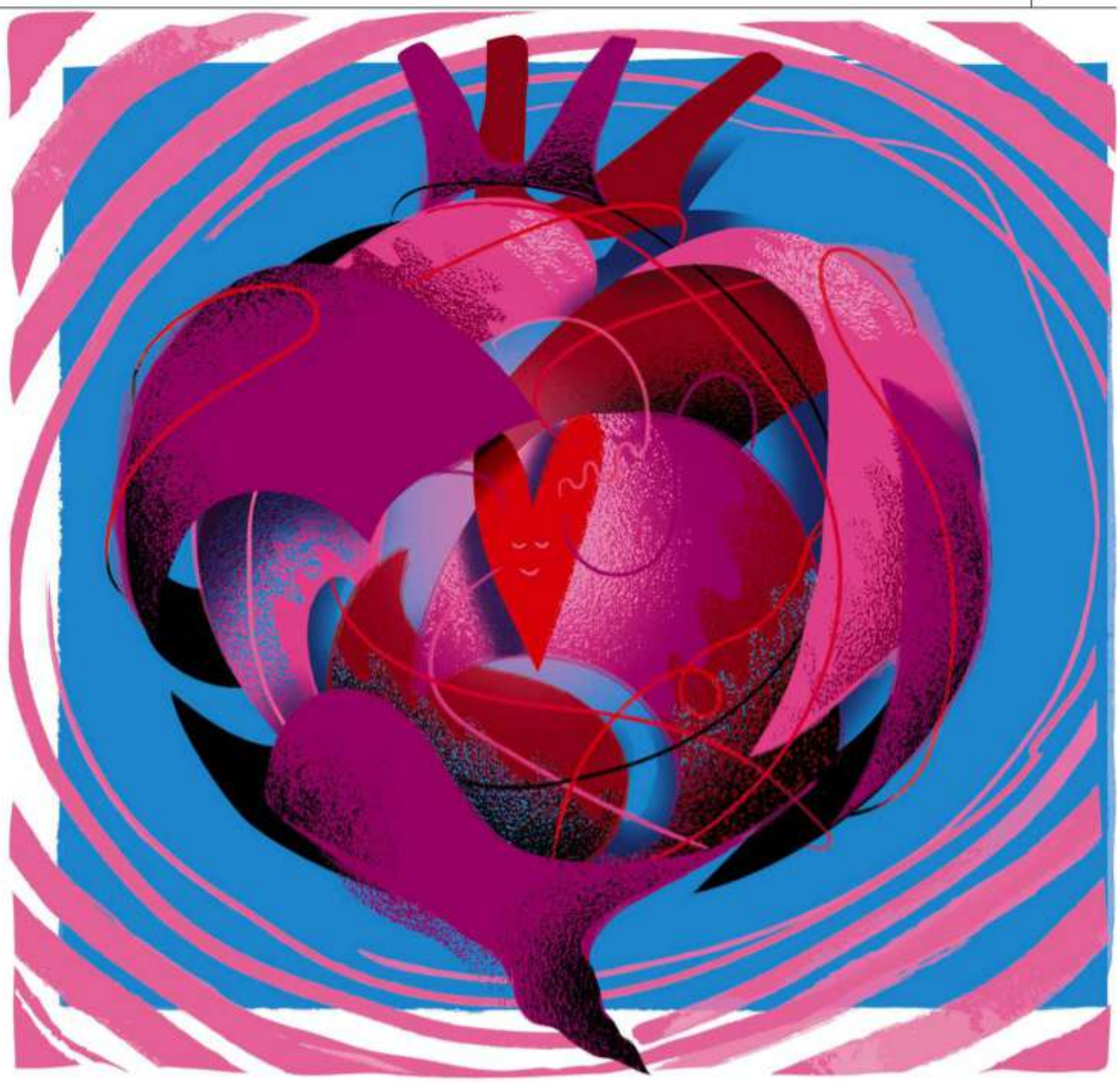
ANCIENT MAMMALS
with ***Dr Elsa Panciroli***

The new series of *Just One Thing* is available now. Tune in on BBC Radio 4 on Wednesdays at 9:30am, or listen on BBC Sounds.

COMMENT

YOU CAN'T BEAT BEETROOT

How this humble, purple vegetable can improve the health of your heart



Last year I made a podcast series for BBC Radio 4 called *Just One Thing*, which was an unexpected hit. The idea is that each week I look at one thing you incorporate into your daily life which might have delightful, unexpected benefits. We ran a feature on this in *BBC Science Focus*, and the whole of series one and two (all 20 episodes) are available on BBC Sounds.

Well, I've got a new series which has just started and it kicks off with me making the case for consuming more beetroot, one of the few vegetables that lives up to claims of being a 'superfood'. Beetroot gets its colour from betalains, powerful antioxidants that are present throughout the plant, but it is the high levels of nitrates that give beetroot its magic powers.

When we consume nitrate-rich vegetables such as beetroot, something remarkable happens. Bacteria that live in our mouths turn the nitrate into nitrite. The nitrite, in turn, is changed by the body into nitric oxide, which, among other things, increases blood flow to various organs, including the penis. Adequate levels of nitric oxide are essential for producing and maintaining an erection, which may explain why the Romans used beetroot juice as an aphrodisiac. Although I haven't yet seen any clinical trials showing that consuming beetroot juice will have a Viagra-like effect, there is evidence that the expansion of blood vessels it causes results in other significant changes.

"Munching a couple of beetroot a day would translate into a reduction in their risk of stroke and heart attack"

A few years ago we did an experiment on my BBC Two series, *Trust Me, I'm A Doctor*, where we took a group of volunteers with raised blood pressure and asked them to feast on a diet rich in beetroot. After a few weeks we found that munching a couple of beetroot a day led to a fall in average blood pressure of about 5mmHg, which, if maintained, would translate into a reduction in their risk of stroke and heart attack of about 10 per cent.

The benefits of beetroot aren't confined to helping those with raised blood pressure. There has also been a lot of research, much of it carried out by Andy Jones, a professor of applied physiology at the University of Exeter, showing that consuming beetroot – particularly in the form of concentrated juice – can enhance your athletic ability.

In one of his early studies he asked a group of club-level competitive cyclists to compete in a couple of time trials, covering 16km, after drinking beetroot juice. What they didn't know is that on one occasion they had normal beetroot juice, on another occasion the beetroot juice had the key ingredient, nitrate, removed. What happened? Well, the cyclists were, on average, 45 seconds faster when they were nitrate powered, which in a competition would be massive. Beet that.

If you find the flavour of beetroot juice too strong and earthy, try flavouring it with apple, celery and a little ginger. And as for the vegetable, well you can incorporate it into risottos, burgers, bread and even cake (it goes well with chocolate). SF

MICHAEL MOSLEY

Michael is a health writer and broadcaster, who presents *Trust Me, I'm A Doctor*. His latest book is *The Fast 800 Keto* (£9.99, Short Books).

BBC TWO

PORTRAIT: KATE COPELAND ILLUSTRATION: CHRISTINA KALLI

COMMENT

WHY GOOGLE IS JUST A MASSIVE TO-DO LIST

It's the world's most popular search engine, but ultimately, it's just helping us to tick off our intentions

Most people think of Google as a search engine. But inside the building, they know what it really is: a collection of intentions.

Long before digital technology cornered the market on intentions, we were writing them down using a pen under the heading 'To Do'. I am a great maker of these kinds of lists – daily tasks, weekly workflow, fantasy holiday destinations, bucket lists. I've used special apps, special pads of paper, special notebooks. All of these things let me think I'm a few crossed-off words away from being my best self. And that is what a search engine does too: it moves what you want done one step forward.

A friend has been haphazardly documenting other people's shopping lists for several years. When she discovers one discarded in the bottom of a trolley, she takes a photo and posts it online. These are little windows into the world of the person whose hands held the handles before her. It's easy to get lost in the storytelling crumbs. Taken out of context, they say volumes. Taken in aggregate, lists can be even more revealing.

Recently, there was an exhibition at the Museum of Everyday Life in rural Vermont called *A Life In Lists And Notes*. These weren't lists and notes from notable people, but everyday folks who dug through their pockets and drawers to participate in a collection of mostly humdrum desires. As one commentator put it, "Only when put all together do we realise that to-do lists are important records of how we spend our time."

"It created an algorithm that collects, analyses and processes our wants"

Google knows all this. It takes our to-do intentions and it serves up the solutions, based on the aggregated to-dos of people who it thinks are just like us. Its killer innovation was to create an algorithm that collects, analyses and processes our wants in the context of the wants of everyone else who uses its service, long after we might have forgotten we wanted them. The problem is, Google can't distinguish between a personally more valuable want and something we just need to cross off a list to move onto the next thing. Nor can it tell if we're messing with it.

Comedian and author Morgan Bassichis began writing lists each Monday in 2017. In the list dated 21/8/17, "Weigh in on the antisemitism debates online" is crossed out and is followed by "Explore bracelets!". By 18/3/19, item one was "Find a therapist who can work quickly." The lists were archives of the emotional chaos they felt about the political situation in the US of that time, notes for their stand-up act, and a record of the routine and the impossible. The collection was published in 2020 as *The Odd Years*, and the book makes compelling and surreal reading. But it leaves the reader unsure about whether anything ever got done.

Which brings us back to Google. Things gets complicated when our to-dos are never crossed off, never forgotten, and are applied without nuance or context to the person who wrote them down. Aggregating intentions has made the company far more money than the people who published the list apps or the clever notepads. But has the human got lost in the process? SF

ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *The Digital Human*.

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Dinosaurs: The Final Day, with Sir David Attenborough, is available now on BBC iPlayer.

THE DAY THE DINOSAURS DIED

New BBC documentary, *Dinosaurs: The Final Day*, presented by Sir David Attenborough, digs into a fossil site that may have recorded the moment an asteroid wiped out almost all life on Earth. **Holly Spanner** met with **Robert DePalma**, one of the palaeontologists at the site, to find out more about the significance of this discovery...

YOU'VE BEEN WORKING AT TANIS, A TOP-SECRET FOSSIL LOCATION IN NORTH DAKOTA. WHEN WAS THIS SITE LAID DOWN?

We worked out the site was deposited during the fallout of coarse ejecta material [debris] from an asteroid impact. To give it probably the broadest span possible, we can say the site is constrained [dated] to the first one to two hours [after asteroid impact], maximum, because that's how long ejecta would have been falling for.

HAVE YOU FOUND ANY OTHER EVIDENCE THAT THIS SITE WAS CREATED RIGHT AFTER THE ASTEROID IMPACT?

We have constrained the site in multiple different ways, using plants, pollen, marine dinoflagellates and different organisms. In addition to that, we have physics. When the asteroid hit, material was thrown out of the crater [as vaporised and molten rock] and out of the atmosphere, where it cooled and solidified, then fell back to Earth in a rain of glowing glass droplets, or spherules. These spherules would have started to arrive at Tanis tens of minutes after impact, raining down for around an hour, two at most. The impact glass has been radiometrically dated, and it dates to the very end of the Cretaceous. Basically, it correlates exactly with the Chicxulub impact event [the moment the asteroid that wiped out the dinosaurs hit Earth in Mexico].

WHAT IS THE SIGNIFICANCE OF THE SPHERULES?

You're dealing with stuff that was molten by the impact, and they therefore contain contamination from the impactor itself.

When glass goes into the ground, it absorbs water. Over time, glass turns to clay. But some of these spherules were trapped in amber before getting deposited, so they were preserved [as glass]. And, in some, we're able to identify little fragments of stone. Most are calcium-rich, probably part of the carbonate platform from the Yucatán Peninsula. But a couple of those fragments were wildly different. They were enriched in nickel, iron, chromium, and a few other elements not common here on Earth. Our preliminary analyses are supporting the fact that those fragments probably came from the impactor itself!

HOW BIG ARE THE FRAGMENTS?

The spherules themselves are one to two millimetres in diameter. And the fragments that we're dealing with are around half a millimetre. Look at the period [fullstop] at the end of a sentence. That's basically the size.

HOW WERE THE FOSSILS PRESERVED SO WELL?

It appears much of the site was deposited by a massive surge of water, not long after the Chicxulub impact. This massive wall of water and sediment came into the river valley, and basically 'locked in' that period of time, like a snapshot into prehistory.

HOW DID AN IMPACT 2,000 MILES AWAY CAUSE A SURGE AT TANIS?

All the flow indicators showed this massive surge that ➲

"This massive wall of water and sediment came into the river valley, and basically 'locked in' that period of time, like a snapshot into prehistory"

ALI PARESY/BBC

essentially went backwards up a river, inland. We looked at all the different diagnostic clues, and it looked like a tsunami. But the numbers didn't match up. A tsunami coming from the crater [in Mexico] could not have reached Tanis [in North Dakota] during that two-hour window. It would have taken around 18 to 20 hours. Well, what did arrive there within that time frame? My colleague Mark Richards figured out that it was seismic waves. When we have the arrival of seismic waves, and a massive surge of water at the same time, the evidence indicates the surge was triggered, in some way, by seismic waves. And that's not without precedent. It's happened multiple times in recorded history.

ONE OF THE FOSSILS IS A DINOSAUR LEG. HOW DID YOU FEEL WHEN YOU SAW THE PATCH OF SCALES EMERGING FROM THE MUD?

That surprise was absolutely genuine. I was excavating a fossil palm frond, the trowel flipped up a piece of matrix, and there were scales underneath, gleaming up at me! Whenever we find soft tissue out there, we're always on alert. Because that's your golden moment to learn, and it's not always available to palaeontologists – we're used to dealing with bones, mostly. Soft tissue preservation opens a whole new door for research. So, we were really excited. And as more and more became exposed, we were able to see this was not just a patch of skin. There was a joint and a bone sticking out. And then eventually, a whole dinosaur leg!

WHAT CAN WE LEARN FROM THIS DINOSAUR LEG?

Firstly, it contains soft tissue features of the scales, unknown for that type of dinosaur. So we've got a much better idea of what that dinosaur looked like. Furthermore, that dinosaur existed right at that moment. Even if it died, for the sake of argument, months before; those dinosaurs existed right up until the end of the Cretaceous. In addition to that, the leg had some tearing to the skin, which gives us an idea, probably, as to the forcefulness of the surge. We already know it was incredibly forceful, based on other animals and plants that were preserved. But this is just one more line of evidence; it was a turbulent surge that mirrors what we've seen in river floods today. Where you've got a turbulent flood, you've got logs and large objects in that flood, and animals get caught up in that, it's almost like a meat grinder. They're literally ripped open in those events. And it appears something much like that could very well have happened here.

I HAVE TO ASK ABOUT THE TURTLE FOSSIL...

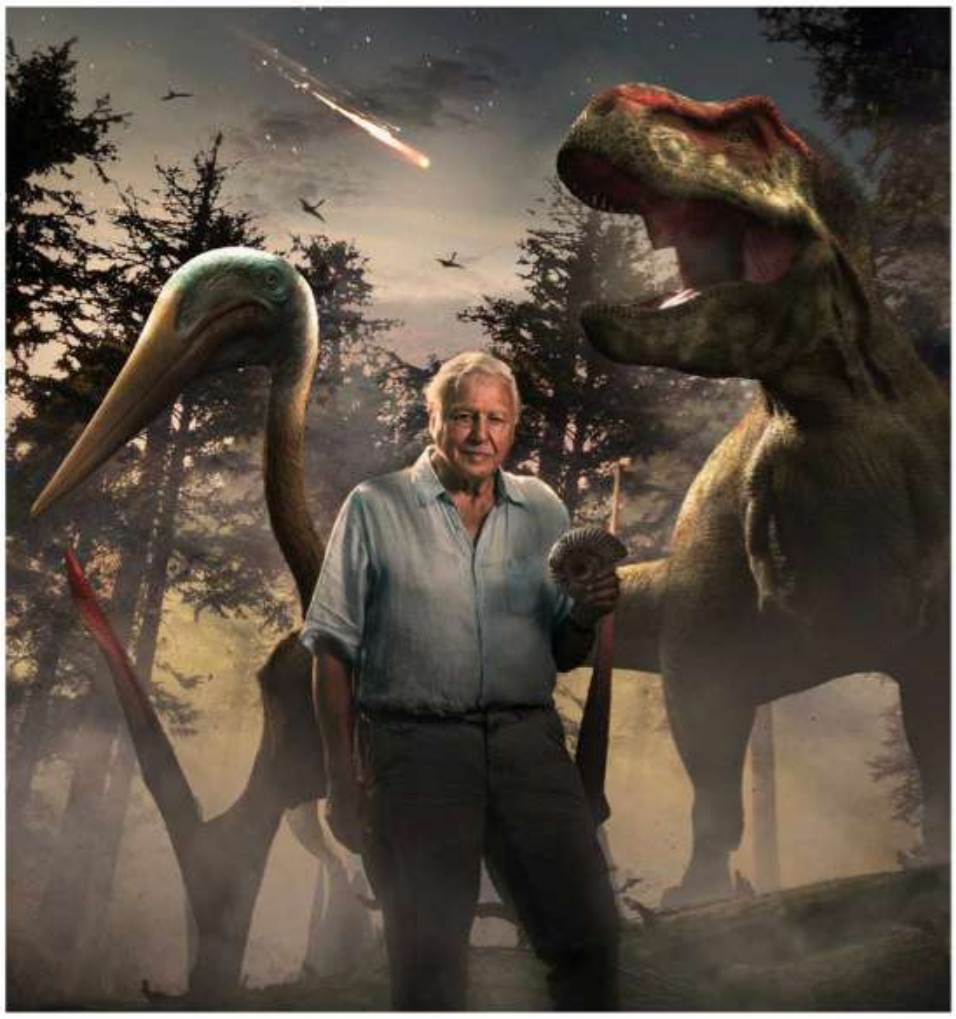
Oh, the turtle, yes! It was totally unexpected. There was this little bit of shell sticking out and it turned out to be a whole turtle. And then, we find that it's skewered on the end of a branch. The minute we saw the branch going through the shell, we thought, "Oh, this poor thing!" The branch goes in one end, and out the other, out the leg opening. We can see both ends of this branch; this thing was thoroughly impaled. Our hearts really went out to the turtle. There is a slight chance it might have died within the weeks before the surge – that's probably our longest timespan to consider, but it's more likely it died in the surge because of that impaling. But it's a glorious little fossil. The shell is perfectly preserved, and that turtle is now able to tell us its own, personalised story.

AND THE BABY PTEROSAUR...

The baby pterosaur was unexpected, because it

"If you survived the surge, you essentially would have had a front-row seat to the end of the Cretaceous. Debris would have been falling out of the sky"

ABOVE Robert DePalma after using liquid nitrogen to successfully free the turtle fossil



was found a little higher up in the surge deposit. We found this little object, the size of a hen's egg. And at first, we thought, could it be a nut, or a seed? But as it was prepared and put under magnification, we noticed these little, delicate, hollow bones. We consulted pterosaur experts, including David Unwin, and it became clear to us that this was an unhatched pterosaur embryo. Pterosaur embryos are unknown from North America, they're unknown from the Late Cretaceous, and they're unknown from that particular type of pterosaur.

It was identified as an azhdarchid pterosaur and would have hatched at about the size of a bat, so it would have been this adorable, bat-sized little creature. We call them 'flaplings' when they come out of the egg, because they, probably, could have flown right out of the egg. I love the word.

ABOVE Sir David Attenborough digs deep into the discoveries at Tanis in *Dinosaurs: The Final Day*

DID YOU FIND EVIDENCE OF ANIMALS THAT SURVIVED THE SURGE?

Yes – and we want to find out why. There's a preserved burrow at the site, where a mammal dug through the surge deposit, after the surge. And we have bones of two mammals, the same species, same age, in that burrow. It's an interesting snapshot of how mammals were coping at that moment. Without this impact event, if the dinosaurs were not taken out, it's possible that mammals would never have diversified to the extent they have, and humans might never have come to be. This is a really pivotal moment in our history.

IF YOU COULD FIND ONE THING AT TANIS, IN YOUR WILDEST DREAMS, WHAT WOULD IT BE?

My gosh. We found a handful of fossil feathers, so if we were able to find any sort of a feathered organism there, either a bird, or one of the feathered dinosaurs, I would be absolutely blown away! We know the preservation potential is there, so it's in the back of our minds that it could be just waiting there.

WHAT DO WE KNOW ABOUT THIS DAY SO FAR?

This day was very, very bad. You have a 10km-wide object hitting Earth at perhaps 20km/s. And, once that happened and all the ejecta was flying through the air, not long after, you would have felt ground shaking in North Dakota. The animals would have known something was wrong. Soon after that, the spherules fell from the sky in a glowing rain of hot molten glass. And not long after that, if the animals weren't perturbed enough, they would have seen a massive surge of water coming up the river valley. But it wasn't beautiful tropical water. It was a muddy, roiling mass of death, with logs, branches, animals and fish, all tumbling together. If you were unlucky enough to have been caught in it, you probably would have been killed instantly. But if you survived the surge, you essentially would have had a front-row seat to the end of the Cretaceous. Debris would have been falling out of the sky, the skies would have turned dark with the dust, ash and everything else, and you would have had three to 10 years of impact winter and ecological collapse.

IN THE CONTEXT OF WHAT IS HAPPENING TODAY, CAN YOU EXPLAIN WHY THIS NARRATIVE THAT YOU'VE UNCOVERED IS SO IMPORTANT?

That brings the story full circle and highlights why the work at Tanis is so important. When you talk about mass extinction events, the Chicxulub impact was one of the top five. The other mass extinctions happened over tens of thousands, to millions of years. And geologically speaking, that's a mass extinction. But the Chicxulub impact happened rapidly. And this highlights the importance of hindsight, offered by the fossil record, to understand the reaction of our modern biomes to global-scale hazards. We can use that window to see how these animals are going to respond, to better understand our current crisis. This could be very important to navigating the waters of our current environmental crisis. And as a species that's able to comprehend this, it's up to us to actually use the data to do that. SF

ROBERT DEPALMA
Robert is a palaeontologist and postgraduate researcher at the University of Manchester, and an adjunct professor at Florida Atlantic University.

IAN KELLETT/BBC STUDIOS, BBC/ALI PARES/SAM BARKER/CHRIS LAVINGTON-WOODS/LOLA POST PRODUCTION

GETTY IMAGES

DOES YOUR DOG REALLY LOVE YOU?

Sure, they wag their tails to greet us and are happy to snuggle up and watch TV in the evening, but are our beloved pooches actually experiencing the same love for us as we feel for them?

by JULES HOWARD

Every morning, as I prepare his food, our black-and-white lurcher, Ozzy, looks up at me with the warmest of eyes. He will give me the eyebrows too. The cutest of smiles. He will cock his head in expectation of food, and seems to know that I will give it to him, devoted as I am.

"Does he really love me?" I wonder, as he waits patiently for his tripe with his tail wagging furiously. Because sometimes I have the vaguest feeling I am being hustled. Like I am one of Pavlov's dogs and he is Pavlov, conditioning me with cuddles and baby-faced eyes to do nice things for him.

Is this love or something else? Can dogs ever really love their humans like we love them? It turns out that questions like these have a rich scientific history, with an exciting conclusion that could forever change our relationship with dogs.

The story of dogs and emotions begins in the Victorian era, when the question sparked one of the first culture wars in history. It involved banners, placards and leaflets. It had burning effigies and vandalised statues, angry marches and speeches in packed-out town halls. At one point, hundreds almost fought in the street. They were ready to fight about whether emotions like love were uniquely human or common to many animals, particularly social mammals such as dogs.

On the one side were those who drew support from Charles Darwin's ideas about how mammals (including humans) share common ancestors. They argued that dogs were capable of many (or all) of the emotions we feel, differing only by degree. On the other side were medical scientists who saw dogs as little more than automatons – machine-like subjects acceptable for medical experiments. The medical scientists favoured a rational, objective approach to their craft – one that found sentimental ideas about whether dogs have emotions to be both unprofessional and even unethical, because it threatened to hold back the progress of medical science.

About objectivity, the medical scientists had a point that is still relevant today. It is clear that many animal scientists in the modern era remain reticent about the use of the term 'love' in non-human animals because the concept is too subjective. After all, if generations of poets cannot agree on a definition of love, then what hope might science have? This is why many dog researchers prefer the word 'attachment' when referring to the bond that dogs have with us.

"Attachment is a particular, measurable aspect of love; specifically to the reassurance that an individual can gain from the presence of a beloved other," explains Dr Clive Wynne, dog behavioural scientist and author of *Dog Is Love*. "It is particularly talked about in the strong bond between parent and child, and that makes a good model for the relationship between dogs and people."

Wynne thinks of love as an everyday term. Not suitable for scientific papers or articles, but permissible for common use. But he certainly does not shy away from the L-word when describing his own doting companion, Xephos.

"We love her. She loves us," Wynne has argued. "Actually, she loves almost everybody. She very, very rapidly makes these strong, powerful connections with people."

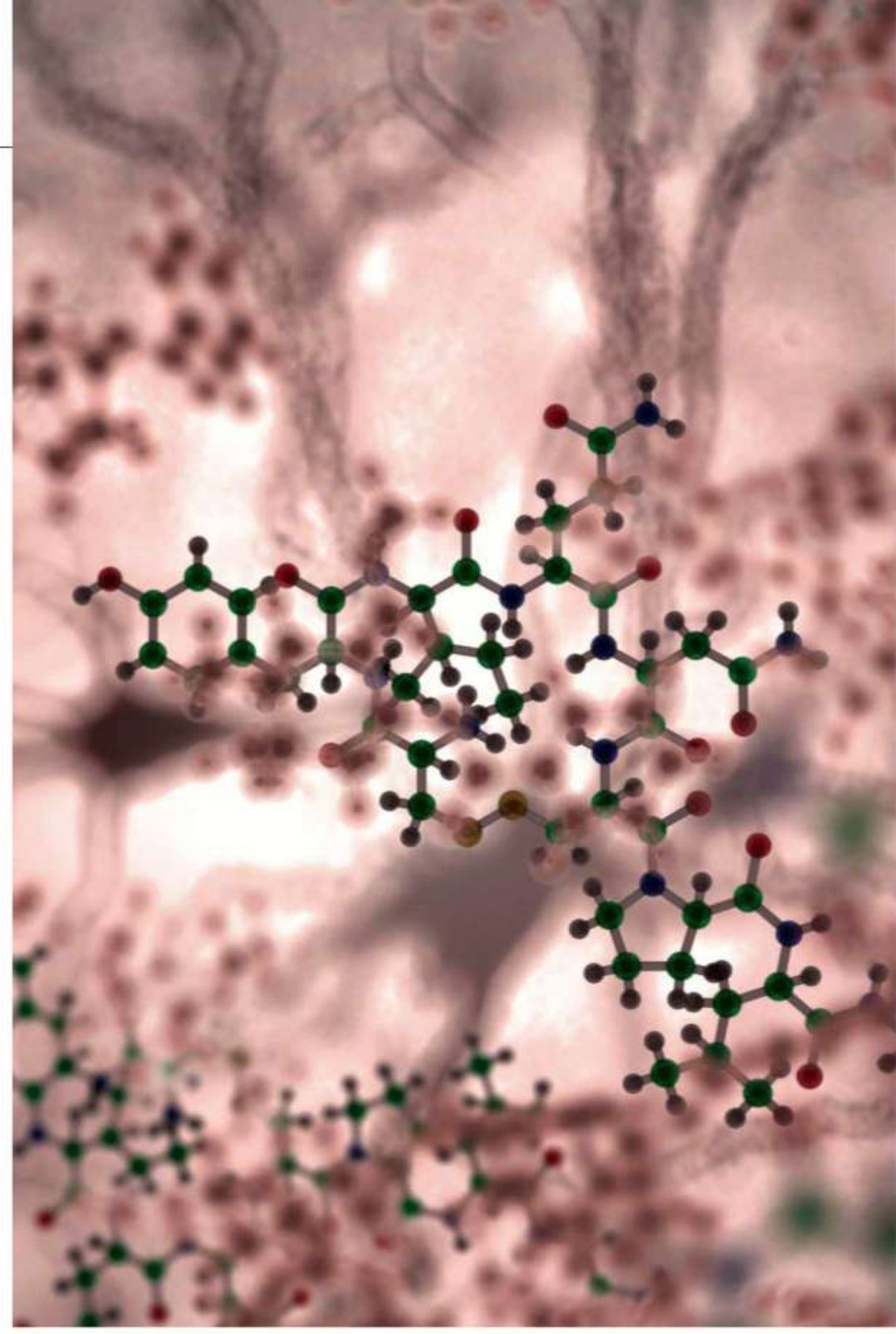
STUCK ON YOU

Dogs really do appear to attach, psychologically, to their human companions in a way we recognise. In tests that involve 'strangers' walking into a room that already contains a dog and its human companion, for instance, dogs react in a manner broadly comparable to human children. In uncertain environments, they'll spend more time near their human companions and, when left alone with strangers, dogs spend more time nearer the door.

BELOW Dog behavioural scientist Dr Clive Wynne gets some puppy snuggle time

RIGHT Even when hand-reared, wolves do not seem to attach to their caregivers in the same way as domestic dogs

FAR RIGHT The hormone oxytocin surges in both dogs and their human companions when they look at each other



Domestic dogs seem naturally to attach to their human companions in other ways. In one experimental setup where dogs and hand-reared wolves were offered the choice of food or their caregiver, many dogs, as well as investigating the food, also came to their caregivers for cuddles and attention. Wolves, predictably, thought only of their stomachs.

In another experiment, where human caregivers feigned being stuck in a box, their dogs showed signs of distress, crying and whining and pawing at the box to help the caregiver escape.

"Dogs really do seem to look up to their humans in a way similar to the love between child and parent," adds Wynne.

Even the physiological mechanisms – the brain hormones and neurotransmitters – that control these attachments appear comparable between humans and dogs. Most prominent is the role of oxytocin, a molecule associated with pleasurable emotional states in mammals. Oxytocin is especially important in humans. It surges, particularly, when breastfeeding or during sex, acting as a natural drug that promotes the social attachment that helps guarantee the survival of genes into future generations. Dogs have surges in oxytocin when they attach with other dogs but, crucially, they also have the same oxytocin surges around humans. In fact, when dogs and their human companions look into each other's eyes, oxytocin levels in both species rise dramatically. In one study, just half an hour of loving glances between humans and their dog companions was all it took to see levels of oxytocin more than double.

"ATTACHMENT IS A PARTICULAR, MEASURABLE ASPECT OF LOVE – SPECIFICALLY TO THE REASSURANCE THAT AN INDIVIDUAL CAN GAIN FROM THE PRESENCE OF A BELOVED OTHER"

DOWN TO THE DNA

Why have dogs evolved to be like this? Why do so many domestic dogs attach to humans so strongly? In recent years, research into the genetic makeup of dogs has offered some interesting insights into why this might be. Most notable is that dogs are social by nature. Quite literally, they have sociality written into their DNA, upon two genes GTF2I and GTF2IRD1 that are known to influence social behaviours in mammals, including humans. Mutations on these genes can lead to more sociable behaviour.

"The average dog carries two to four of these insertion mutations, with some breeds – or groups of breeds – carrying far fewer while others can have many more," says Bridgett vonHoldt, an associate professor of evolutionary genetics ➲

DEANNA DENT/ASU, GETTY IMAGES, ALAMY

at Princeton University. "It is rare, but not impossible, to find dogs that carry more than six mutations."

As luck would have it, vonHoldt's dog, a smiling, bounding sheepdog known as Marla, scores a five. For this reason, she is termed 'hypersocial'.

"It has been amazing to watch her grow up and develop her personality," vonHoldt says. "Whether I blame her genetics or upbringing, Marla is quite bossy when it comes to demanding attention. For people she knows well, she is indignant if there is a conversation happening that is not focused on her with simultaneous scratches and adoration."

In 2017, vonHoldt and colleagues completed their research into how GTF2I and GTF2IRD1 differed in frequency across dog and grey wolf populations, concluding that there was a "strong genetic aspect" to the ways in which dogs interact with humans. Food is likely to have been a key part of those early interactions.

"Those early wolves that carried as few as one or two mutations that influenced their social behaviour could very easily benefit from closer interactions with nearby human settlements and villages," vonHoldt explains. "As this association with humans began to pay off, these mutations became more frequent, paving the way for dogs as you and I know them today."

This means that a big part of the dog's evolutionary history is down to two things: the survival of the fittest and the survival of the friendliest. A struggle for life; a struggle for love. It's all written in the deep history of dogs.

Research like vonHoldt's explains why and how dogs attach easily. But they get us no nearer to the big question: what does this attachment feel like for the dog? Is the love that we feel for our dogs in any way like the love they give back? How could we ever know for sure?

ABOVE Evolutionary geneticist Bridgett vonHoldt with her dog, Marla, whose genetic mutations make her hypersocial

IT'S ALL IN THE BRAIN

For more than 100 years, this philosophical quandary about objectivity was the intractable boulder blocking science's way. But new experimental approaches are starting to see this boulder ever so slightly wobble, exposing exciting new lines of research. Leading the way is a black-and-white mixed breed called Callie, the first dog to willingly enter a functional Magnetic Resonance Imaging (fMRI) scanner and have her brain scanned.

Callie is something of a Rosetta Stone for those interested in the science of what animals can think and feel. In 2012, her human companion (the neuroscientist Prof Gregory Berns of Emory University) carefully devised a training routine to get her used to the loud noises and tight spaces within an fMRI scanner. This training routine proved so successful that it was later used with other dogs volunteered by their human family members.

What Callie and these other dogs proved is that the brains of dogs light up with emotions in a manner that broadly resembles human brains. Especially interesting was the discovery that the pleasure centres of Callie's brain were aroused, not only upon being informed of upcoming food rewards, but also when their human companions made a surprise appearance to say hello. Even the smell of Callie's human companion was enough to see Callie flush with pleasure, just as a human adult would upon seeing a child or vice-versa.

"A BIG PART OF THE DOG'S EVOLUTIONARY HISTORY IS DOWN TO TWO THINGS: THE SURVIVAL OF THE FITTEST AND THE SURVIVAL OF THE FRIENDLIEST"

The conclusion? It's love… or something close. It's attachment, the same as we know.

So, what now? Should this glut of recent

ABOVE Callie was the first dog to be trained to willingly enter an MRI machine to have her brain activity scanned

discoveries about dogs and their unique attachment to us change how we treat them? If dogs feel things like we do, is there more responsibility on us to make their lives better? Debate on this issue, in particular, rumbles on.

"Perhaps it time to rethink our relationship and move away from considering ourselves as owners?" argues Holly Root-Gutteridge, a postdoctoral dog researcher at the University of Lincoln. She prefers 'guardianship' as a descriptive for our relationship with dogs. "We guard their physical health, why not their emotional health too?"

Dr Sean Wensley, senior vet and author of *Through A Vet's Eyes*, agrees: "Recognising the capacity for animals to experience feelings means that, morally, we must meet those animals' welfare needs when they are under human care," he says. "As our scientific understanding of those needs grows, so, practically, we can better tailor our care to ensure our dogs' physical and emotional needs are both met."

More than 100 years ago, science and society clashed about love. Today, thanks to some incredible discoveries, the two sides are more united than ever. But the human relationship with dogs is far from fixed in stone. It will continue to change, as new scientific discoveries light the path. The love affair between us is far from over. Our unique attachment continues. **SF**

by **JULES HOWARD** *(@juleslhoward)*

Jules is a zoologist and science writer. His latest book, Wonderdog *(£17.99, Bloomsbury Sigma), is out now.*

CHRIS FASCENELLI/PRINCETON UNIVERSITY, BRYAN MELTZ/EMORY UNIVERSITY, GETTY IMAGES X4, ALAMY

THE LANGUAGE OF LOVE

SOFT EYE CONTACT

Direct prolonged eye contact can be quite intimidating for most dogs. But if your dog is happy to share soft gazes with you, it can mean that they feel comfortable connecting with you in this way.

BIG WAGS

"Most of us know that dogs are happy to see us when they treat us to a full body wiggle and wagging tail," says Claire Stallard, animal behaviourist at welfare charity Blue Cross. "But look for the 'helicopter tail' when the tail spins like a propeller – this is often reserved for a favourite person."

NAPS AND LAPS

To keep warm and secure, dogs are fond of napping alongside one another. Often, they will actively choose family members they feel attachment with specifically for this purpose. "It's important to remember that cuddling must always be on your dog's terms," says Stallard.

LICKING

Dogs lick people for many reasons. It's their way of gathering information about where you've been and they may even enjoy the salty taste on our skin. "However, many dogs seem to do it as a sign of affection particularly when they are saying 'hello' to someone they like," Stallard adds.

NICE TO GREET YOU

Many dogs undergo a significant positive emotional response when reunited with their human companions after a period apart. When reconnecting, look for tail-wagging, a full body wiggle, soft gazes, and an open mouth, often with tongue lazily exposed.

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Q&A

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... HOW DO THE CHAMBERS OF THE HEART WORK?
... HOW DO TEARLESS ONIONS WORK?
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... DO DOGS KNOW WHEN THEY FART?
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... WHAT IS BALL LIGHTNING?
... WHY DO KIDS GO HYPERACTIVE WHEN IT'S WINDY?

Email your questions to
questions@sciencefocus.com
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DR NISH MANEK
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DR HELEN PILCHER
Biologist and science writer

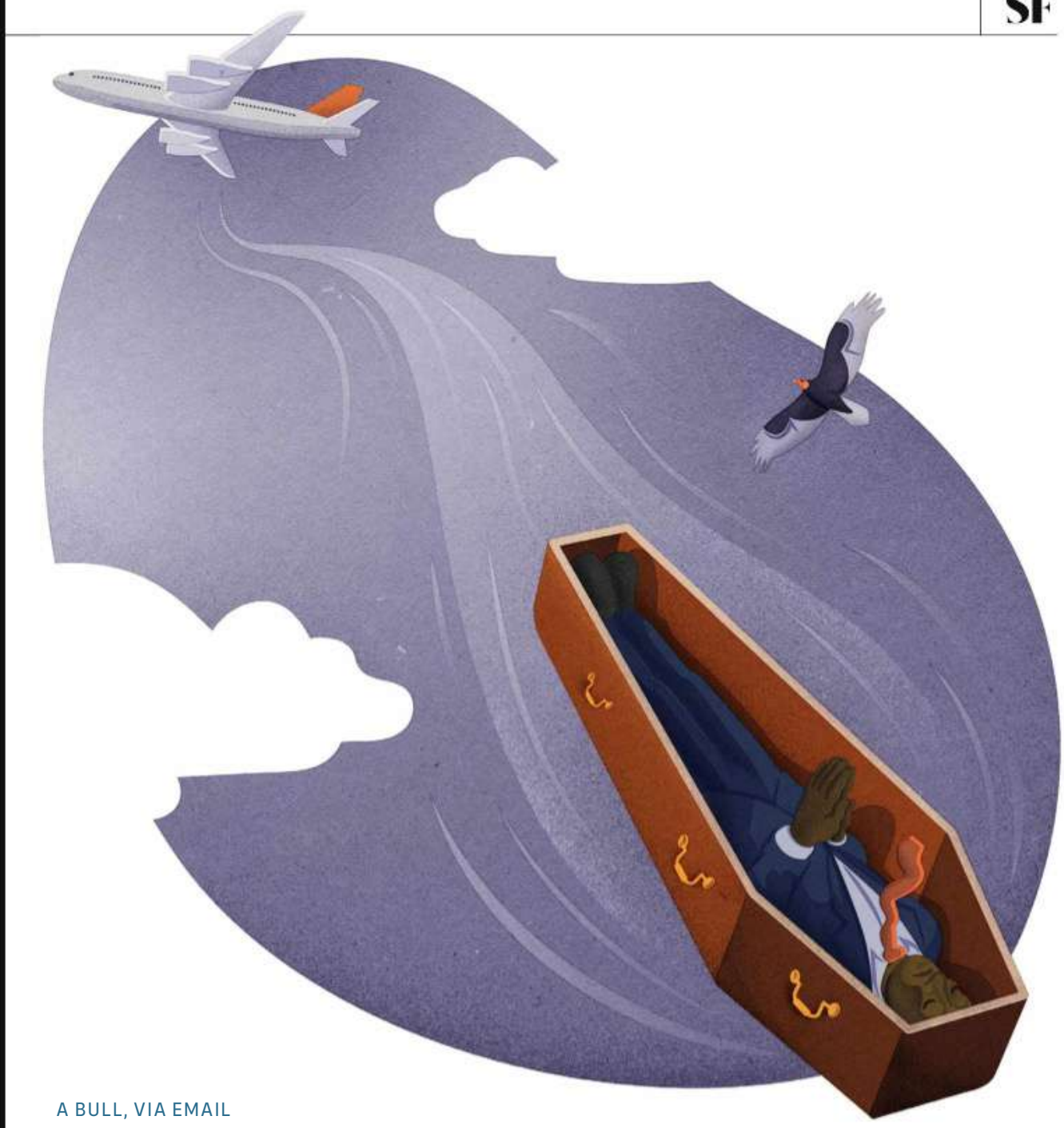


ILLUSTRATION: DANIEL BRIGHT

A BULL, VIA EMAIL

IF I FELL OUT OF A COMMERCIAL AIRCRAFT, WOULD I BE DEAD BEFORE I HIT THE GROUND?

A commercial jetliner cruises at around 830km/h at an altitude of 10,000m. Quite apart from the fact that the doors are locked automatically while in flight, the pressure differential at that altitude is more than five tonnes per square metre. Aeroplane doors open inwards so it would be like trying to open the door with an elephant sitting on it.

All of this means that in order to fall out in the first place, something very bad must have happened to the plane itself, such as an explosion or catastrophic structural failure, which is already likely to cause serious injury. Assuming you survive that, and don't hit the wings or tail on your way out, you will find yourself in air at less than a quarter of the normal sea-level pressure, and temperatures of -48°C.

The US Federal Aviation Authority gives a "time of useful consciousness" of just 30 seconds at this altitude. This is the period where you can still react rationally to your surroundings before the lack of oxygen overcomes you. Beyond this point, you will be groggy and disorientated and will soon pass out, but you won't asphyxiate.

Studies in the 1960s found that chimpanzees could survive up to three and a half minutes in near vacuum without any long-term effects. Of course, you are also falling this whole time at about 200km/h, so every minute brings you 3,300m closer to the ground. At most, this gives you three minutes to endure atmospheric conditions that are getting milder the further you fall.

After that, you have much bigger problems to worry about. Only one person has ever survived a fall from an aeroplane at that altitude: flight attendant Vesna Vulović who was on JAT Flight 367 in 1972 when it was blown up at 10,160m by a terrorist bomb. But she was trapped inside the damaged fuselage, which partially cushioned her impact. ***LV***

ASTRONOMY FOR BEGINNERS

Lyra sits approximately two-thirds up the sky above the eastern horizon around midnight. Vega is the fifth brightest night time star and fairly easy to identify.

The object marked as M57 is the Ring Nebula, an example of a planetary nebula formed when a dying low mass star puffs its outer layers out into space. M57 requires a telescope to see properly.

LYRA THE LYRE

WHEN: MAY AND JUNE

Considered a summer pattern, the small constellation of Lyra the Lyre is actually visible for most of the year. In fact, its brightest star Vega, never sets from much of the UK, but instead appears to scrape the horizon when it lies due north. During May and into June, Lyra appears roughly two-thirds up the sky above the eastern horizon around midnight.

Vega is the brightest star in the large asterism (unofficial pattern) known as the Summer Triangle, the two other vertices marked by Deneb in Cygnus the Swan and Altair in Aquila the Eagle. From the UK, Deneb appears left and down a bit from Vega at this time of year, while Altair is a little lower than halfway between Vega and the horizon. For a while, Vega was used as the reference point against which the brightness of all other stars was measured, representing a value known as zero magnitude.

Immediately below Vega is a parallelogram of stars that represents the main body of the lyre, a harp-like musical instrument. Identify the nearest star in the parallelogram to Vega and imagine the two stars forming one side of an equilateral triangle. The third vertice in this triangle is located to the left of Vega. Stare carefully at this star and with good eyesight, it should be possible to split it into a pair.

Amazingly, through a telescope each of these components can be split again. This appearance has led to this star, formally known as Epsilon Lyrae, being nicknamed the Double-Double.

On the morning of 16 May, the Moon will undergo a total eclipse as it passes into Earth's shadow. This will be a tricky event to see from the UK, as the main part of the eclipse will begin at 2:27am with maximum eclipse at 5:11am just before the Moon sets. ***PL***

RAY SMITH, VIA EMAIL

WHY DO TREES HAVE SUCH SHALLOW ROOT SYSTEMS?

Tree roots need access to water and oxygen held in underground pockets called soil pores. With ideal soil and moisture conditions, trees can send roots down to great depths. But conditions are often less than ideal, with stones, bedrock or compact soil physically halting them in their downward path as well as reducing oxygen levels. When life gets tough the roots take the easy option, staying close to the surface and spreading out a long way from the tree. Drought conditions can also cause some trees to have shallow root systems so that they can maximise rainfall collection by being nearer to the surface. ***ED***

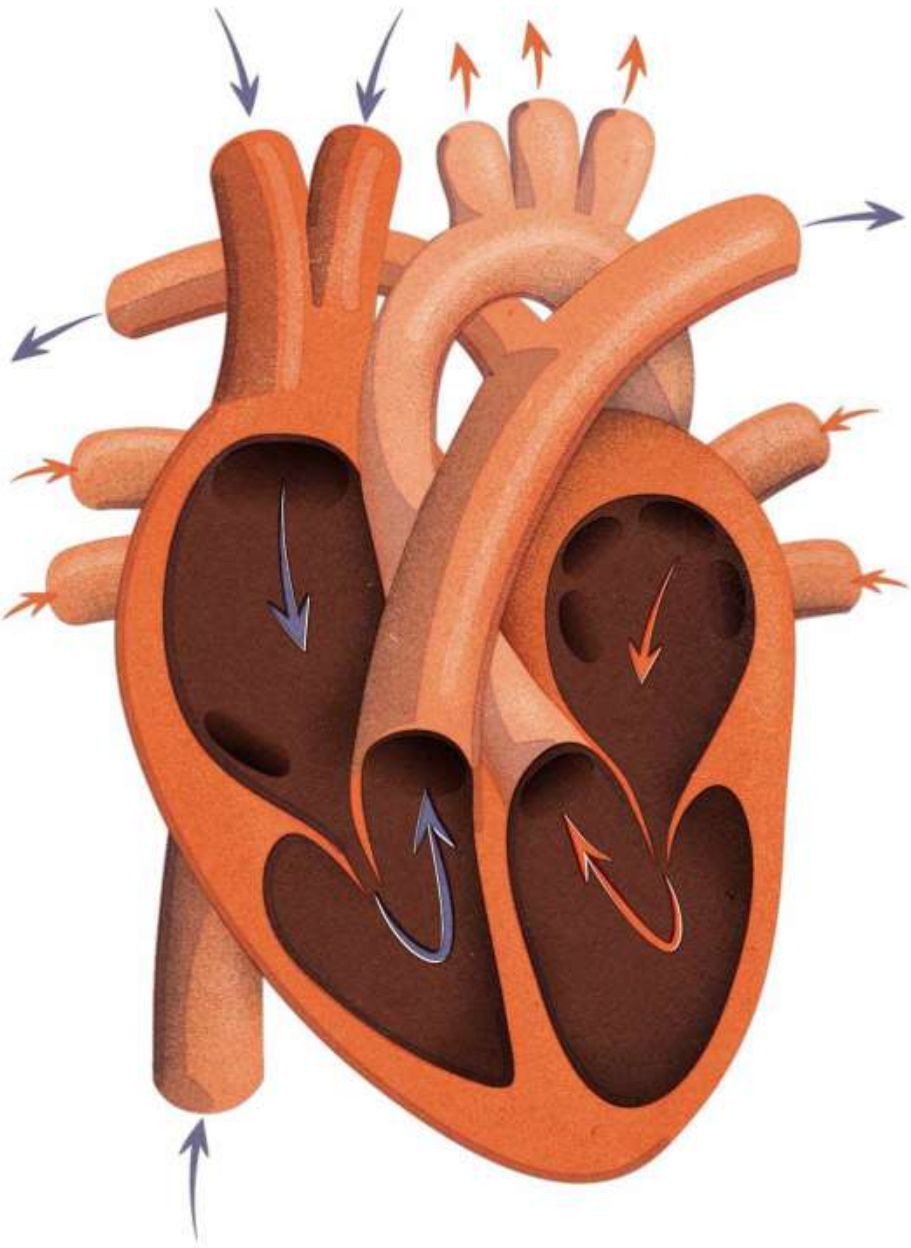
JAMES MOORE, VIA EMAIL

HOW OFTEN SHOULD I REBOOT/SHUT MY COMPUTER DOWN?

It depends on the computer. A Windows computer should be shut down, or even better, restarted, once a week or so with 'fast startup' turned off to ensure it properly shuts down all processes and cleans up. Mac computers tend to be a little more stable and may only need to be restarted with system installs or upgrades.
A Linux machine usually needs few restarts.

One advantage of a restart is that it clears everything from memory, which might resolve misbehaving applications – a slow computer running hot for no obvious reason may need this remedy as a last resort. However multiple power-downs per day may stress the machine and reduce its lifespan. ***PB***

HOW DO THE CHAMBERS OF THE HEART WORK?



A heart has four chambers in total – two upper, and two lower. The upper chambers, called the right and left atria, receive incoming blood. The lower chambers, the more muscular right and left ventricles, pump blood out of the heart.

About five litres (eight pints) of blood is being pumped around the body all the time. The heart, blood and blood vessels together are known as the cardiovascular system. So how does this system work?

The right atrium receives blood that is relatively low in oxygen, because it has been used up by the body. It passes through a valve and enters the more muscular right ventricle. When the ventricle contracts, it pumps the blood out of the heart to the lungs, so it can pick up a fresh supply of oxygen. The blood then goes back to the left side of the heart and enters through the left atrium. It passes through a different valve into the left ventricle, and from there it is pumped out to the rest of the body to supply it with oxygen.

This whole process is known as the cardiac cycle. Contraction of the heart muscle is known as systole, and relaxation of the heart muscle is called diastole. When the valves close in turn, this causes the heartbeat.

Very rarely there are congenital defects in the wall between the two sides of the heart, such as having a 'hole in the heart'. Mild defects often don't need to be treated, but more significant defects sometimes need surgery to correct them. ***NM***

GETTY IMAGES, DANIEL SOTTO MAIOR ILLUSTRATIONS: PETE LAWRENCE, DANIEL BRIGHT

NATURE'S WEIRDEST ANIMALS...

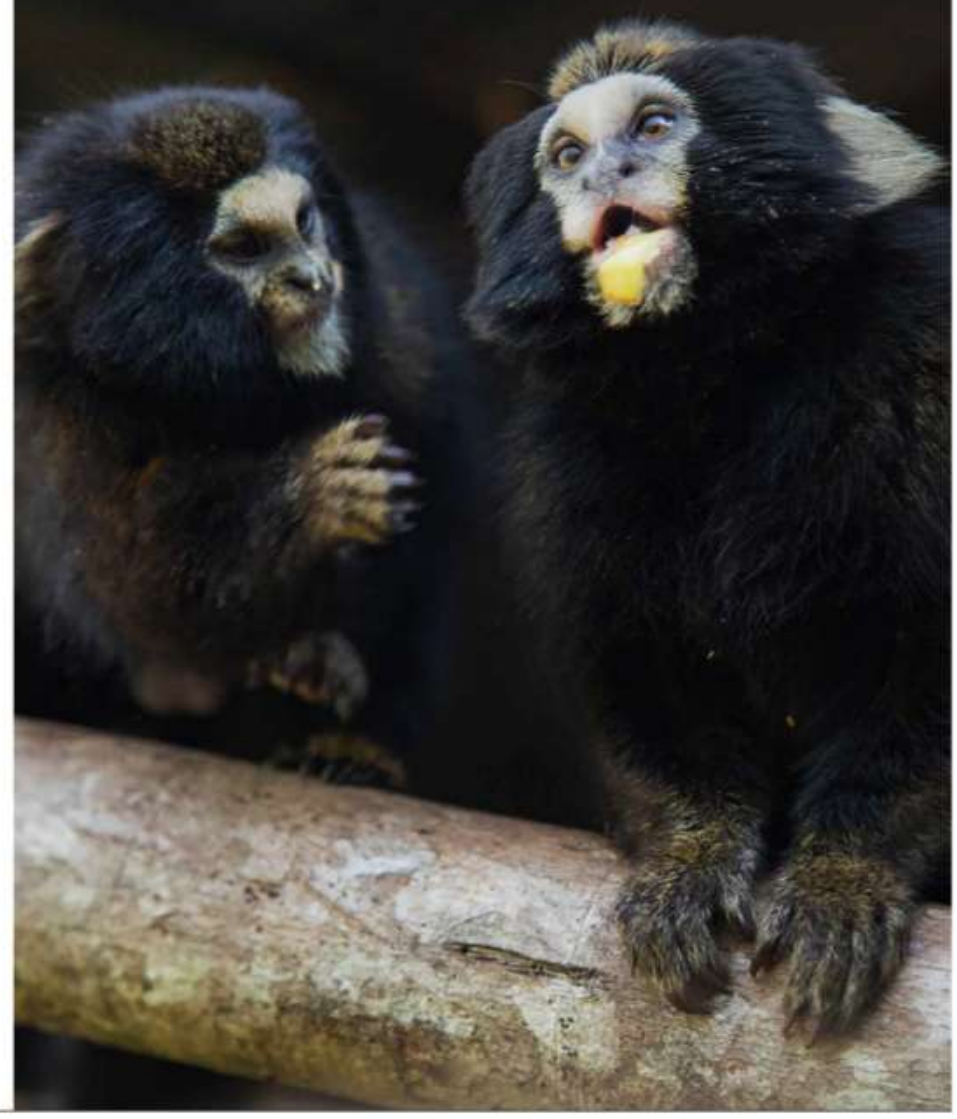
BUFFY-TUFTED MARMOSET

If you know your marmosets, then the buffy-tufted marmoset is weird. Even if you don't know your marmosets, it's still pretty kooky. With its protuberant ear tufts and pallid grey face, it looks like a cross between Krusty the Clown from *The Simpsons* and Robert Smith from The Cure. Some conservationists even call it the 'goth marmoset,' while in Portuguese it's known as *sagui caveirinha*; the 'little skull monkey.'

It bucks the marmoset trend by not eating tree sap and not looking cute. Its relatively short snout and small incisors make stripping tree bark difficult, so it dines instead on insects and fungi. Dwelling in the mountainous regions of the southeastern Atlantic Forest in Brazil, its haggard face is set into a permanent grimace.

Other marmoset species, such as the common marmoset, are not only more photogenic, they're also invading the buffy-tufted marmoset's patch, where they're hybridising with it, and pushing it to the brink of extinction. Add to that, there is the omnipresent threat of yellow fever, and the fact that 93 per cent of the marmoset's native forest has been razed to make way for agriculture.

What's really weird about the buffy-tufted marmoset is not its expression or its odd eating habits, but that so few people seem to know or care about it. ***HP***



SARAH HARRIS, VIA EMAIL

HOW DO TEARLESS ONIONS WORK?

Slicing through an onion damages cells, causing enzymes and other substances that are normally kept apart to spill out and react together. In standard onions the result is a sulphur-containing chemical called *syn*-propanethial-S-oxide, which resembles tear gas. This forms an irritating acid when it comes into contact with water in your eyes. Some research groups have created onions that are genetically modified to lack an enzyme that leads to *syn*-propanethial-S-oxide, but these have not yet made it to market.

The tearless onions – Sunions – now in shops were created by repeatedly cross-breeding milder varieties containing lower levels of pyruvate. This substance is a by-product of the same reaction that forms *syn*-propanethial-S-oxide and also has a good measure of pungency. ***ED***

CROWDSCIENCE

Every week on BBC World Service, *CrowdScience* answers listeners' questions on life, Earth and the Universe. Tune in every Friday evening on BBC World Service, or catch up online at **bbcworldservice.com/crowdscience**

BBC WORLD SERVICE CROWD science

ARE WE TOO SELFISH TO SAVE THE PLANET?

It's true we have some selfish tendencies – we're highly motivated to seek out personal pleasure, and to protect and support our own people, be that family or a larger 'in-group'. But we've also evolved to cooperate, and many people have strong instincts to be altruistic.

Part of the challenge for environmental campaigners is the scale and apparent remoteness of the climate crisis. It's not that we're too selfish to save the planet, but rather our psychological makeup means that we find it harder to empathise with the needs of thousands of people far away than with a single person in front of us. For survival reasons, we also have a strong tendency to prioritise immediate pressing concerns as opposed to problems in the future that we can't see.

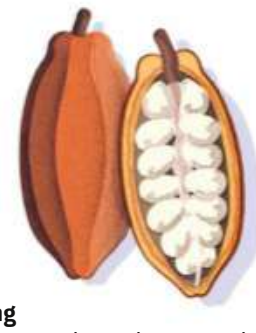
The good news is that being more aware of our psychology offers up plenty of ways to galvanise people into collective action to help address climate change. For instance, we're influenced by other people's behaviour and what seems to be 'normal'. By spreading the word that more people are recycling or avoiding using petrol cars, this will encourage others to do the same. Likewise, recognising our bias for local and immediate concerns suggests campaigns will be more effective if they convey the urgency of the climate crisis, including its likely imminent adverse effects on our friends and family. *CJ*

GETTY IMAGES X3, ALAMY ILLUSTRATION: DANIEL BRIGHT

HOW IS CHOCOLATE MADE?

Chocolate is made from the beans of *Theobroma cacao*, a small evergreen tree from the rainforests of South America. Translating as 'food of the Gods' in Greek, its elongated pods grow up to 35cm, and vary in colour from bright yellow to deep purple. Archaeological evidence suggests we've been indulging in cacao products since around 3,300 BC.

1 **Growing**
The *Theobroma cacao* tree is grown in the rainforests of South America.



2 **Splitting**
The cacao pods are harvested, then split open to reveal the beans in a juicy white pulp.

3 **Fermenting**
The pulp and the beans are scooped out, then careful fermentation develops the flavour.

4 **Drying**
The beans are dried to remove moisture content.

5 **Roasting**
Roasting develops the flavour and sterilises the beans, killing microorganisms (like bacteria) on the outer shell.

6 **Cracking**
The roasted beans are cracked, separating the husks from the beans.

7 **Winnowing**
Winnowing removes the lighter husks and dust particles, leaving the heavier beans or 'nibs'.

8 **Grinding**
The now shell-less beans are ground up, and sugar is added.

9 **Tempering**
Slowly heating and cooling the chocolate allows the fats to crystallise uniformly and the chocolate to break with a satisfying snap.

10 **Moulding**
The mixture is poured into a mould where it cools.

JOSHUA HIGGINS, VIA EMAIL

CAN A VASECTOMY BE REVERSED?

In a vasectomy, the tubes that carry sperm from the testes to the penis are blocked or cut. Reversing a vasectomy involves rejoining these tubes, which isn't always successful. Moreover, it is not usually available on the NHS, and can cost several thousand pounds privately. The success rates of a reversal are not high – about 75 per cent if done within three years of the original procedure, falling to around 55 per cent up to eight years, and 40 per cent up to 14 years. Because of the low chance of success in reversing it, a vasectomy should be thought of as a permanent procedure for those considering it. ***NM***

CARYS EVANS, CARDIFF

DO DOGS KNOW WHEN THEY FART?

Best! Question! Ever! Some dogs clearly react to their own farts, by acting surprised or by moving away. Perhaps surprisingly, scientists take canine flatulence seriously. Twenty years ago, researchers at the WALTHAM Petcare Science Institute designed a dog jacket that can be used to harvest rectal gases, and subsequently determined that the main malodorous component is hydrogen sulphide. Dedicated to the core, they went on to show that the dog olfactory system contains hydrogen sulphide-responsive cells. This proved, at the molecular level, that dogs have the capacity to detect their own farts. ***HP***

DEAR DOCTOR...

HEALTH QUESTIONS DEALT WITH BY *SCIENCE FOCUS* EXPERTS

I REGULARLY WORM MY PETS, SHOULD I WORM MYSELF, TOO?

More than 1.5 billion people, or 24 per cent of the world's population, are infected with worms worldwide, known as helminth infections. They tend to be more prevalent in tropical and subtropical areas, in particular sub-Saharan Africa, the Americas, China and East Asia.

The World Health Organization (WHO) currently recommends deworming drug treatment once or twice a year for all children living in areas where soil-transmitted helminths are endemic. There is evidence that these worms can have a significant impact on growth and development of children, and can affect their cognitive development in the long run. In these countries, the WHO also advises that women of reproductive age (including pregnant women in the second and third trimesters and breastfeeding women) and adults in certain high-risk occupations – such as tea-pickers or miners – undergo regular deworming.

However, this recommendation does not extend to all adults, and certainly not in the UK. For now we should stick to deworming pets regularly. UK children only need to be treated when they have symptoms (usually worms can be seen as little threads in the child's poo). If treating a symptomatic child, then the whole household needs treating, even if they do not have symptoms, to try and prevent further spread. ***NM***

ELLA MICHAELS, VIA EMAIL

WHAT IS SLEEP INERTIA?

Sleep inertia is the groggy state we sometimes experience upon waking. It is most noteworthy during the first 15 to 30 minutes after we wake up. During this state our cognitive functioning dips – something which improves once we have been awake for a while.

In an excellent review of the topic published in the *Nature And Science Of Sleep* in 2019, authors Cassie Hilditch and Andrew McHill point out that while sleep inertia can occur in the absence of risk factors, it is worst when waking occurs during the 'biological night'; after we have previously missed out on sleep; and that it might also be linked to deeper sleep. Indeed, it is sometimes recommended that naps are limited to 15-20 minutes in order to reduce the likelihood of sleep inertia occurring. Research continues on the neurophysiology of this state, but certain differences in brain activity and connectivity have been flagged in the awake brain before as compared to after sleep.

Sleep inertia could also reflect adenosine being inefficiently cleared from the brain during sleep – as caffeine has been found to be effective in reducing sleep inertia. We do not know whether sleep inertia is associated with certain advantages, but one intriguing hypothesis flagged in the aforementioned review is that this process could encourage us to stay asleep rather than become fully awake following unwanted disruptions to our sleep.

Sleep inertia can have real-life consequences (it increase the risks of accidents when driving, for example) and is the reason why we should always give ourselves time to wake up fully after sleep and before getting on with the day. There is currently a lack of effective and practical methods to reduce sleep inertia, but the study of exercise as a method of reducing sleep inertia may prove fruitful. ***AG***

OSCAR BROWN, VIA EMAIL

WHAT IS BALL LIGHTNING?

Ball lightning is a mysterious and unexplained form of lightning which has puzzled weather watchers for millennia and continues to intrigue researchers today. The phenomenon is generally described as a ball of light that appears during thunderstorms. The size of the ball varies, from a golf ball to larger than a football, and it tends to hover over the ground. Its lifetime varies too, from a few seconds to a few minutes, with larger and dimmer balls tending to last longer.

Observations go far back in history. Luminous balls feature in the legends of the Argentinean and Chilean Mapuche culture, but the earliest known written reference comes from an English monk in 1195. He described "a dense and dark cloud, emitting a white substance which grew into a spherical shape under the cloud, from which a fiery globe fell towards the river". Tsar Nicholas II even reported witnessing the phenomenon in a church in St Petersburg as a young child. A study conducted in the 1960s for the US Atomic Energy Commission found that ball lightning has been seen by 5 per cent of the world's population – about the same proportion as those who have seen a normal lightning strike up close.

Scientists think that ball lightning is real, but how it happens is an open question. In 2014, Chinese scientists captured video of ball lightning while trying to record normal lightning. Their readings show a mixture of silicon, iron and calcium atoms in the ball, all common components of soil. This lends weight to a theory that when lightning strikes soil, it creates a vapour of silicon nanoparticles. These particles react with air to generate light and heat at relatively low temperatures. However, it does not explain observations of ball lightning passing through walls, or aircraft cockpits. Further research will be needed to finally unravel this mystery. ***DG***

QUESTION OF THE MONTH

WINNER

The winner of next issue's *Question Of The Month* wins a **NASA Deluxe telescope**, worth £99.99. This iconic astronomical telescope has a 37cm height-adjustable tripod, a finder scope and three lenses with varying magnification to capture the sights of the skies **iwantoneofthose.com**

KARL STEWART, LEICESTER

WHY DO CHILDREN GO HYPERACTIVE WHEN IT IS WINDY?

There's certainly seems to be widespread belief in this idea. A survey of hundreds of UK headteachers in 2020 found that the overwhelming majority (74 per cent) believed that strong wind is the worst weather for pupils' behaviour, rather than heat, snow or rain. We probably shouldn't dismiss these beliefs out of hand, but from a scientific perspective, there's little evidence to support them. A 1989 study by researchers at the University of Lancashire actually found that slightly fewer children were sent to a 'quiet room' (for disruptive behaviour) on windier days. A University of Nevada study from 1990 looked at a range of weather variables, including wind, and while preschoolers spent less time on their learning materials during stormy weather, they instead spent more time engaged appropriately (so not aggressively) with peers and with teachers. The researchers surmised that children seek out more human company when the weather makes them feel uneasy – a possible effect of wind, then, but hardly consistent with the idea that it makes them hyper. Or consider a study carried out at Carleton University in Canada that also looked at links between young kids' behaviour and weather patterns. In this case, stronger wind had no associations with negative emotions, but it was correlated with the kids being less determined and less active. The researchers speculated this was due to the cold time of year, with the biting wind feeling harsh and demotivating – but again, this doesn't back up the idea of wind making kids go mad.

Based on the little scientific research available, the idea that kids go crazy when it's windy seems to be no more than an urban myth, alongside similar evidence-free but popular beliefs, such as that sugar makes them go wild. ***CJ***

ALAMY, GETTY IMAGES ILLUSTRATIONS: DAN BRIGHT

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM**

THE EXPLAINER

THE SUN

HOW FAR IS THE SUN FROM EARTH?

The distance between the Sun and Earth is, on average, about 149.6 million kilometres. That means that the Sun's light takes about 8.3 minutes to reach Earth. Since the Earth's orbit is slightly elliptical, at its closest point to the Sun (called 'perihelion') it is about 147 million kilometres away, while at its furthest point (called 'aphelion') it is about 152 million kilometres away. This 3 per cent or so difference means sunlight is on average 7 per cent stronger at perihelion than at aphelion. But perihelion actually occurs in early January, in the dead of winter for the northern hemisphere. This demonstrates that it is the Earth's axial tilt which causes the seasons, rather than its proximity to the Sun.

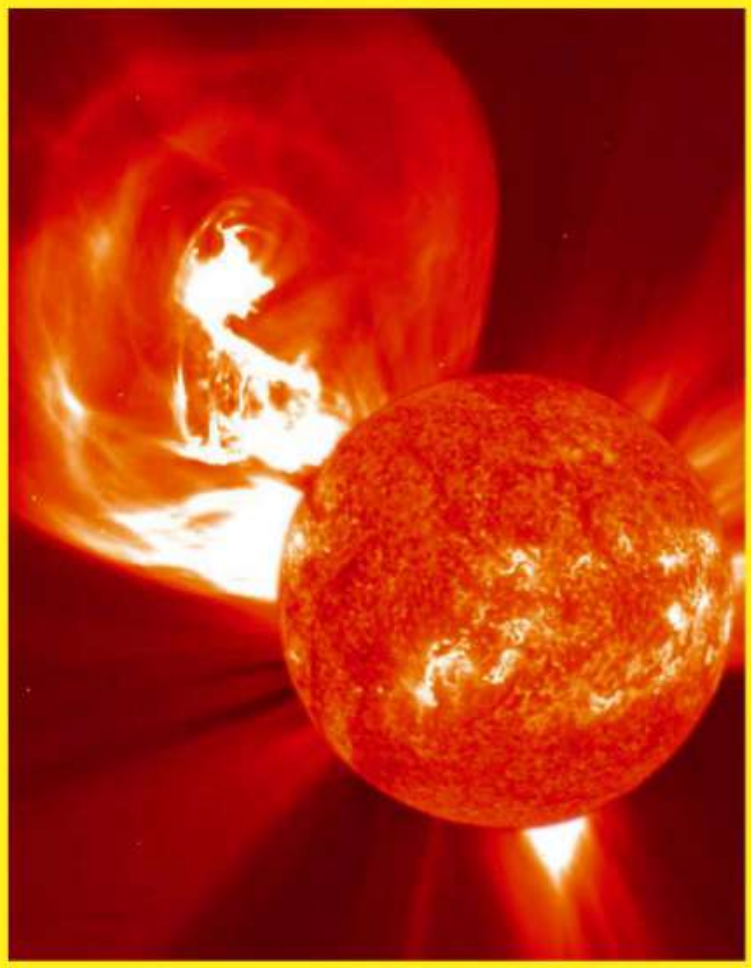
HOW BIG IS THE SUN?

The Sun's radius is about 696,342km, which is roughly 109 times the Earth's radius. This means that you could fit more than 1.3 million Earths inside the Sun.

HOW DOES THE SUN BURN WITHOUT OXYGEN?

The Sun is not 'burning' in the traditional sense of the word. Instead of chemically combining with oxygen, such as carbon does when coal is burnt, the Sun's fuel is undergoing thermonuclear reactions. Most of its energy is produced by the fusion of hydrogen into helium deep in the Sun's core where the temperature and pressure are huge.

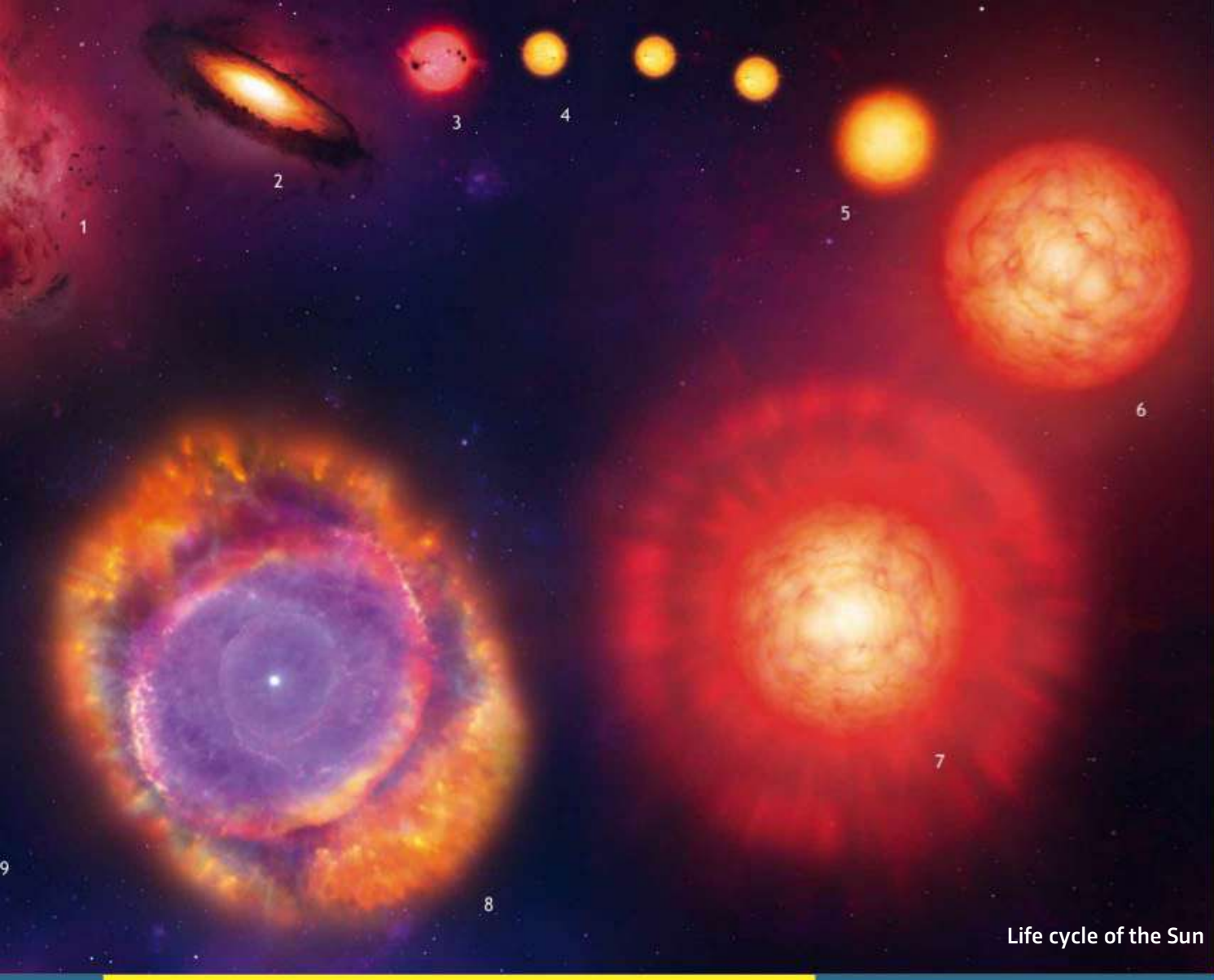
Astronomers calculate that the Sun is losing about 4.26 million tons of mass every second due to fusion (or about 140 quadrillion tons per year). This is only 0.000000007 per cent of the Sun's total mass. This means that even at the end of its life, in about five billion years time, the Sun will still have 99.966 per cent of its current mass!



HOW HOT IS THE SUN?

The Sun is hotter in the middle than at its surface. Right at the core of the Sun, the temperature is about 15,000,000 °C, hot enough for thermonuclear reactions to take place. But at the surface of the Sun, which scientists call the 'photosphere', the temperature is only 5,500°C. Surprisingly though, the Sun's outer atmosphere is actually far hotter than the surface; it is about 2,000,000°C, with some regions even reaching 20,000,000°C.

There is, as yet, no complete explanation for the high temperatures in the solar atmosphere, but it is almost certainly a result of the Sun's magnetic field.



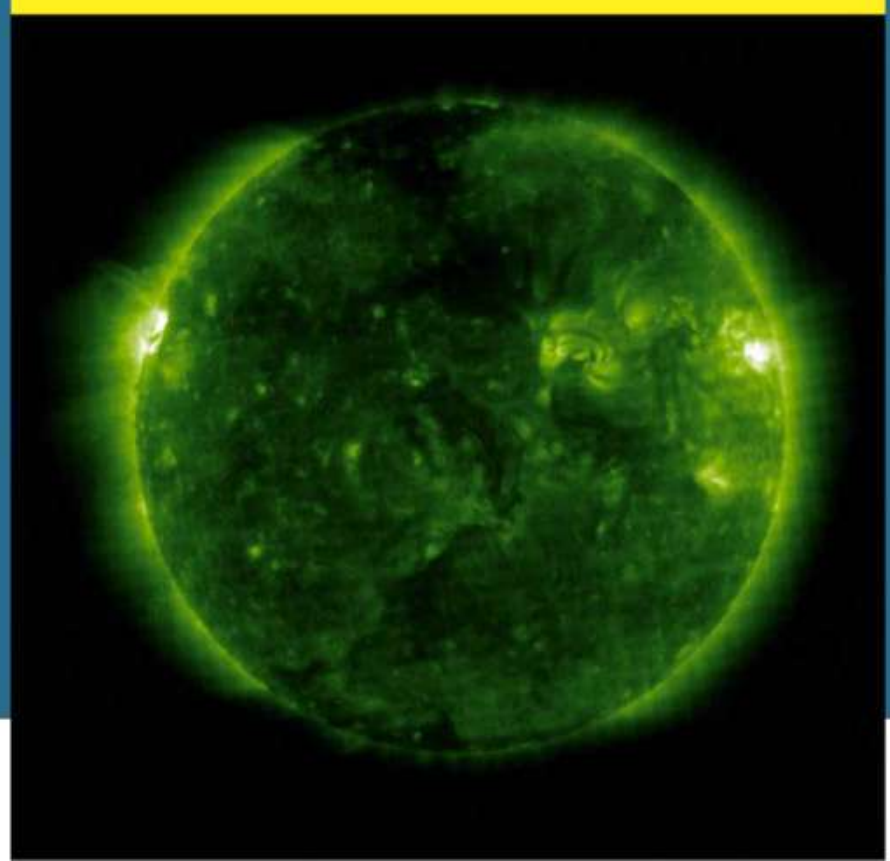
Life cycle of the Sun

HOW OLD IS THE SUN?

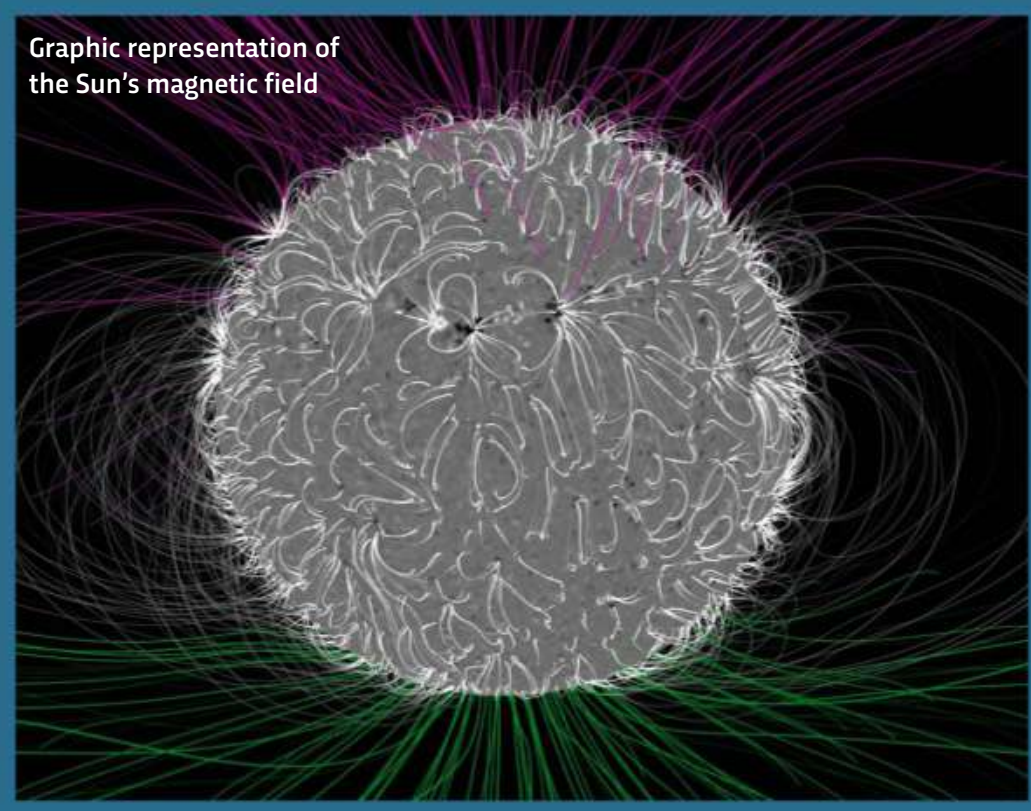
The Sun is about 4.57 billion years old. It is middle-aged, and will live for another five billion years or so. As the Sun reaches old age it will expand and brighten to become a 'red giant' star, eventually engulfing Mercury and Venus. Earth may just about survive the expanding Sun, but about three billion years from now the Sun's energy output will have evaporated Earth's oceans and atmosphere anyway! After about a billion years as a red giant, the Sun will shake off its outer layers, forming a beautiful 'planetary nebula'. Left behind will be a small, hot 'white dwarf', which will survive, cooling slowly, for maybe another trillion years.

WHAT COLOUR IS THE SUN?

The spectrum of light from the Sun peaks at a wavelength which we would normally describe as green. However, across the narrow range of the visible spectrum the amount of light emitted at each wavelength is almost exactly the same. But more crucially, the human eye does not perceive light by averaging the various colours of the spectrum together. So, a very slight excess of green light does not look green to the human eye – it looks white. The Sun would have to emit only green light for our eyes to perceive it as green. So, why does it generally look yellow? It is because the Earth's atmosphere scatters blue light more efficiently than red light. This slight deficit in blue light means the eye perceives the colour of the Sun as yellow. In space, though, the true colour of the Sun is obvious; it is white.



Graphic representation of the Sun's magnetic field



HOW STRONG IS THE SUN'S MAGNETIC FIELD?

The most recent measurements have shown that typical magnetic fields just above the solar surface lie between two gauss and six gauss. By way of comparison, the Earth's magnetic field at the surface ranges between 0.25 gauss and 0.65 gauss, about 10 per cent that of the Sun's. These are actually quite weak magnetic fields. The strength of a fridge magnet is about 100 gauss. The magnet in a typical audio loudspeaker is about 10,000 gauss, while MRIs use magnets of about 30,000 gauss. The strongest known magnetic fields, around objects called 'magnetars' (a type of neutron star), can be as high as a quadrillion gauss. Such magnetic fields would warp all the atoms in your body, killing you instantly!

by DR ALASTAIR GUNN

Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics.

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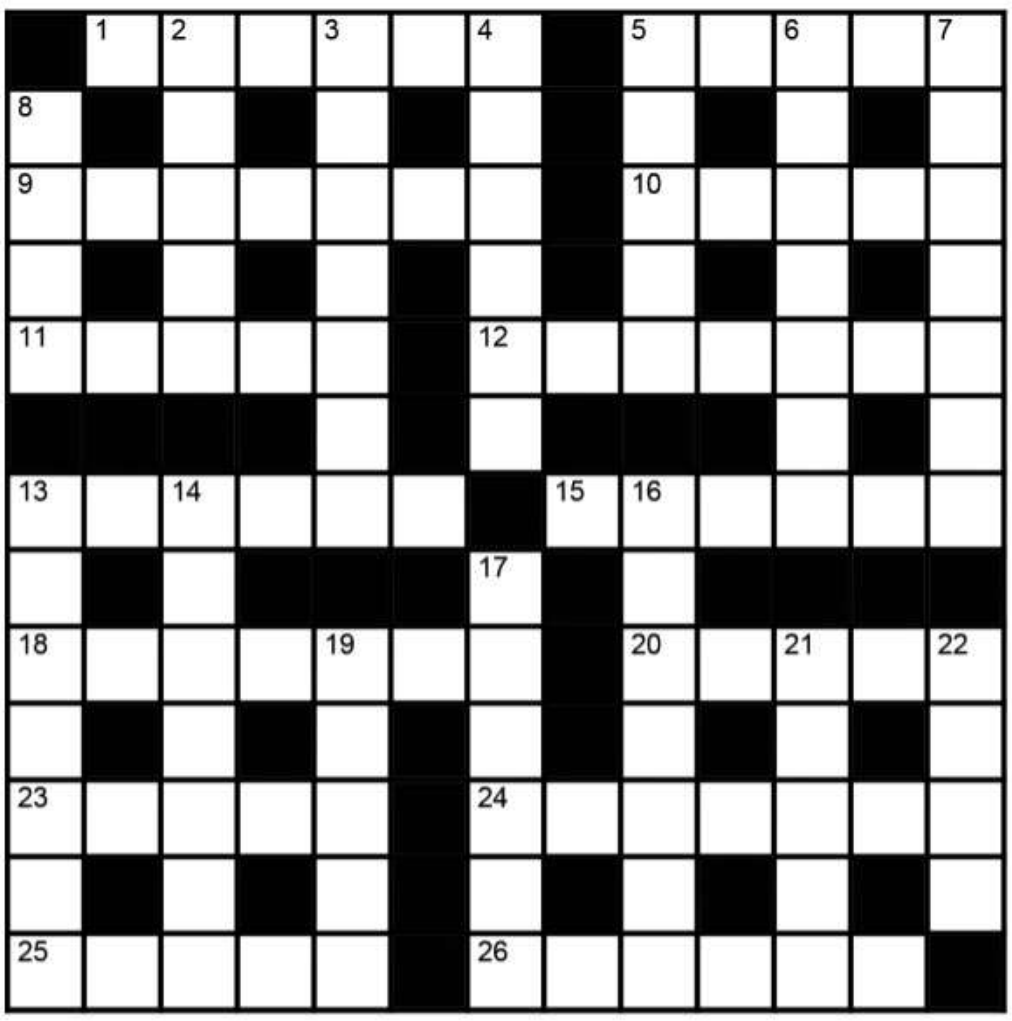
CROSSWORD

PENCILS AT THE READY!



ACROSS

1 A record about having a source of wool (6)
5 Indicate purpose (5)
9 Ad-lib about having funds regularly is loud enough (7)
10 Blockade is returning, say, east (5)
11 Strange niece has spirit (5)
12 Respect strange symbol of royalty (7)
13 Cleric to evaluate copper first (6)
15 Swamp donkey found after second right (6)
18 Reinforce a cushion (7)
20 He wrote of French opponent (5)
23 Elaborate prose that a sailor should learn? (5)
24 Perfect example of cooked pie, as far as I am concerned (7)
25 Very small adolescent comes to sticky end (5)
26 Weaken woman with stringed instrument (6)

DOWN

2 Boy finds space full (5)
3 Surrounding a doctor, that is, with books (7)
4 Game is turned into a form of discrimination (6)
5 Glue for fake jewellery (5)
6 Drink and diamonds affected date (4,3)
7 Article uses new Greek hero (7)
8 Criticise last of strong twinge (4)
13 Feline has uncovered entertainment (7)
14 Romeo to pass time and deteriorate (7)
16 Previous invoice in force (3,4)
17 Monster steals heart of learned ally (6)
19 Thank you pen? That's nice (5)
21 Drift, being part of the parade (5)
22 Get level out of revenge (4)

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

NEXT ISSUE

A GUIDE TO INTRUSIVE THOUGHTS

GETTY IMAGES

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POPCORN SCIENCE

How can I get a real lightsaber?

With *Obi-Wan Kenobi* hitting Disney+, we want to know the feasibility of the Jedi weapon of choice

by STEPHEN KELLY

The lightsaber. For fans of *Star Wars*, samurai movies and accidentally cutting your own arm off, it has long been "an elegant weapon, for a more civilised age" (your childhood). And with the premiere of Disney+'s *Obi-Wan Kenobi* this May, it seems safe to assume that we're about to see a lot more of them. But while every big kid has at one point or another swung a big broom around the house while going 'vwommm', is there any way lightsabers could ever become a reality? Well, to answer that, we need to first figure out what a lightsaber is.

Physicist Patrick Johnson, an associate teaching professor at Georgetown University and author of *The Physics Of Star Wars*, suggests two options.

"The first is that it is exactly what it is described as, a sabre made of light, a laser sword," he says. "The problem with it being a laser, though, is that because photons move at the speed of light, the laser will just keep going until it runs into something. Lasers don't stay in a self-contained beam."

The more plausible option, says Johnson, is that lightsabers are made of plasma, the electrically charged gas that makes up lightning and the Sun. Plasma cutting machines are often used in manufacturing to slice through materials such as steel.

"Plasma is hot enough to melt metal, it can change colour depending on the material you're using and is able to cauterise wounds, just like in the movies," explains Johnson. "But the problem is that it's really, really hot. We're talking about holding something that is the temperature of the Sun in your hand, which is not going to be pleasant for you without special equipment."

There is also the matter of size. Portable plasma cutters are bulky because they need to be attached to a container filled with fuel and a cooling mechanism. And even then, the beams that they produce are typically only a few millimetres long.

The reason for this is perhaps the biggest obstacle standing between you and a fully operational movie-style lightsaber. Because plasma is essentially a soup of ions and electrons, creating a self-contained beam is a big challenge.

"You can have a jet that's shooting out really hot plasma in front of you," says Johnson, "but you're going to almost certainly run out of fuel pretty quickly, because all the stuff you shoot out has to come from somewhere. What you need is plasma that is self-contained and typically the way we would do that is with a magnetic field, but magnetic fields make things go in circles rather than in beams. You might be able to create a very thin elliptical shape that could approximate a beam, but you would have to really work to distort the magnetic field."

Some people have come close to replicating the look of a lightsaber. Last year, Canadian engineer and YouTuber James Hobson used tanks of liquid propane gas and oxygen to create an impressive beam of lightsaber-esque plasma. But as Johnson says, replications like these are "essentially nothing but a fancy crème brûlée torch."

For example, such plasma lightsabers would be incapable of having a duel with another lightsaber. "Because they are made up of charged particles, the two plasmas would just end up being attracted to each other and become one," he says. "It would be like expecting soup to clash with other soup."

So alas, it seems as though our dreams of becoming a lightsaber-wielding Jedi knight like Obi-Wan Kenobi are as dead as he is. But Johnson has hope. "The computers of the 1950s took up entire rooms," he says. "I would never say never." SF

VERDICT

For now, we'll have to make do with swinging a broom around our heads and making our own lightsaber sound effects.

by STEPHEN KELLY *(@StephenPKelly)*
Stephen is a culture and science writer, specialising in television and film.

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